SHALE BLUFF ONE MILE SOUTHWEST OF VEEDERSBURG, FOUNTAIN COUNTY, INDIANA. WORKED BY WABASH CLAY CO.

INDIANA.

. . . DEPARTMENT . . .

. . . OF . . .

GEOLOGY.

—AND—

NATURAL RESOURCES.

TWENTIETH ANNUAL REPORT.

W. S. BLATCHLEY,
State Geologist.

1895.

INDIANAPOLIS:
WM. B. BURFORD, CONTRACTOR FOR STATE PRINTING AND BINDING,
1896.

PLATE I.

INDIANA.

. . . DEPARTMENT . . .

. . . OF . . .

GEOLOGY

—AND—

NATURAL RESOURCES.

TWENTIETH ANNUAL REPORT.

W. S. BLATCHLEY,
State Geologist.

1895.

INDIANAPOLIS:
WM. B. BURFORD, CONTRACTOR FOR STATE PRINTING AND BINDING,
1896.

ASSISTANTS.

T. C. HOPKINS . . . . Assistant Geologist.
E. M. KINDLE . . . . Assistant Geologist.
W. A. NOYES, Rose Polytechnic, Terre Haute, Ind. . . . . Chemist.
ROBERT LYONS, State University, Bloomington, Ind. . . Chemist.
W. P. HAY, Washington, D. C. . . . . Zoölogist.
ROBERT FISHER, Brazil, Ind. . . . . Inspector of Mines.
J. C. LEACH, Kokomo, Ind. . . . . . Supervisor of Natural Gas.
C. F. HALL, Danville, Ind. . . . . . Supervisor of Oil Inspection.

TABLE OF CONTENTS.

INTRODUCTORY.

	Page.
THE NATURAL FUELS OF THE STATE	6
Coal	8
Petroleum	12
Natural Gas	13
RESOURCES OTHER THAN FUELS	14
Soils	14
Limestones	16
Sandstones	17
Whetstone and Grindstone Rocks	18
Clays	18
Iron Ores	20
Sands	20
Marl	20
Other Minerals and Ores	20
NATURAL HISTORY	21
THE STATE MUSEUM	21
OFFICE WORK	22

A PRELIMINARY REPORT ON THE CLAYS AND CLAY INDUSTRIES OF THE COAL BEARING COUNTIES OF INDIANA, BY W. S. BLATCHLEY.

CHAPTER I.—

General Uses of Clays	24
Definition of Clay	24
Properties of Clays	26
Origin and Classification of Clays	29
Impurities of Clays	36

CHAPTER II.—

THE CLAYS OF THE COAL BEARING COUNTIES OF INDIANA	40
Clays of Parke County	47
Clays of Fountain County	58
Clays of Vermillion County	65
Clays of Vigo County	71
Clays of Clay County	77
Clays of Owen County	83
Clays of Greene County	87

Page.
Clays of Sullivan County 91
Clays of Knox County 94
Clays of Daviess County 97
Clays of Martin County 100
Lawrence County Kaolin 103
Clays of Dubois County 106
Clays of Pike County 110
Clays of Gibson County 113
Clays of Vanderburgh County 116
Clays of Warrick County 119
Clays of Spencer County 121
Clays of Perry County 123
ANALYSES OF CARBONIFEROUS SHALES 129
ANALYSES OF UNDER-CLAYS OF COAL MEASURES 133

CHAPTER III.—

THE CLAY-WORKING INDUSTRIES OF THE COAL-BEARING COUNTIES OF INDIANA 134
THE MANUFACTURE OF PAVING MATERIAL 136
Choice of Clays 136
Location of Plant 138
Preparation of Clays 139
Making of Paving Brick 141
Drying of Paving Brick 142
Burning of Paving Brick 143
Cost of Paving Brick Plant 147
Statistics of Indiana Paving Brick Factories 148
Cost of Making Paving Brick 149
The Testing of Paving Brick 149
The Formation of Brick Pavements 152
Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana 156
THE MANUFACTURE OF SEWER PIPE AND HOLLOW GOODS 164
Statistics of Sewer Pipe and Hollow Goods Industries 167
THE MANUFACTURE OF REFRACTORY MATERIAL 168
THE MANUFACTURE OF POTTERY 171
Statistics of Stoneware Potteries 174
THE MANUFACTURE OF DRY-PRESSED BRICK 175
Statistics of Dry-Pressed Brick Factories 177
THE MANUFACTURE OF ORDINARY BRICK AND DRAIN TILE 178
Statistics of Ordinary Brick and Drain Tile 179

THE CARBONIFEROUS SANDSTONES OF WESTERN INDIANA. BY T. C. HOPKINS.

CHAPTER I.—

THE GENERAL CHARACTERS AND PROPERTIES OF SANDSTONE.
Definition 188
Composition and character of the grains 188
Composition and character of the cement 189
Markings on the bedding surface 190

Page.
Varieties of sandstone based on color 191
Varieties based on texture and structure 191
Varieties based on composition 191
Varieties based on locality 193
Uses of sandstone 193
Production of sandstone in the United States 194
Distribution of sandstones 195

CHAPTER II.—

GEOLOGIC HISTORY OF THE SANDSTONES OF WESTERN INDIANA.
Classification of 196
Unconformity 196
Conditions of deposition 197
Source of materials 197

CHAPTER III.—

THE MANSFIELD SANDSTONE.
The name 199
Geologic position 200
Varieties based on color 200
Structure 203
Texture 203
Chemical composition 205
Mineralogical composition 206
Strength 206
Fire test 207
Absorption test 208
Durability 208
Adaptability 211
Distribution 211

CHAPTER IV.—

LOCAL DETAILS OF THE GEOLOGIC FEATURES AND DISTRIBUTION OF THE SANDSTONES IN THE AREA SHOWN ON THE ATTICA AND BRAZIL MAP SHEETS.
Eel River (Walnut Creek) basin 213
Raccoon Creek basin 230
Sugar Creek basin 255
Coal Creek basin 269
Southeast side of Wabash River above Coal Creek 276
North side of Wabash River above Coal Creek 291

CHAPTER V.—

NOTES ON SANDSTONE QUARRIES OUTSIDE OF THE AREA MAPPED.
Vermillion County—Portland stone 306
Clay County—Brazil 309
Greene County—Bloomfield 310
Orange County 309
Dubois County 312
St. Anthony 312
Jasper 313
Perry County—Cannelton 314

CHAPTER VI.— Page.
Summary 315

APPENDIX—
Statistics 318
Analyses 322
Tests 323
Bibliography 323

THE WHETSTONE AND GRINDSTONE ROCKS OF INDIANA. BY EDWARD M. KINDLE.

CHAPTER I.—
TOPOGRAPHY AND GENERAL GEOLOGY 329
Position 329
Topography 329
Drainage 330
Geology 331

CHAPTER II.—
HINDOSTAN WHETSTONE 336
Literature 336
Historical Sketch 338
Structure 339
Manufacture 339

CHAPTER III.—
COARSE SANDSTONE WHETSTONE 342

CHAPTER IV.—
RELATIVE VALUE AND IMPORTANCE OF INDIANA WHETSTONES 343

CHAPTER V.—
WHETSTONE BEDS 345
French Lick Region 348
Orangeville Region 351
Fossil Plants of the Hindostan Whetstone Beds. By David White 354

CHAPTER VI.—
GRINDSTONE GRITS 357
Development 357
Manufacture 358
Distribution 359

CHAPTER VII.—
OTHER ECONOMIC RESOURCES 361
Kaskaskia Sandstone North of Lost River 361
Kaskaskia Sandstone South of Lost River 363
Mansfield Sandstone 365

REPORT OF THE STATE NATURAL GAS SUPERVISOR. BY J. C. LEACH.

Page.

LETTER OF TRANSMITTAL 369
INTRODUCTION 370
NATURAL GAS.
Early History 373
Value of Consumed in United States from 1885 to 1893 375
Chemical Composition of 376
Fuel Value of 379
Origin and Accumulation of 380
Pressure and Measurement 385
The Indiana Field 386
Trenton Limestone 387
Condition of the Indiana Field 391
Rock Pressure in the Indiana Field in 1895 391
Natural Gas as an Illuminant 395
Future of the Indiana Field 396
UTILIZATION OF NATURAL GAS. BY ELWOOD HAYNES 399
LIST OF NATURAL GAS COMPANIES 405

REPORT OF STATE INSPECTOR OF MINES. BY ROBERT FISHER.

INTRODUCTION 412
EXAMINATION OF MINES 413
LABOR DIFFICULTIES AND CONDITION OF THE COAL TRADE 414
STATISTICAL TABLES 416
REPORT ON MINES EXAMINED 433
LIST OF ACCIDENTS DURING THE YEAR 1895 452
CAUSES OF ACCIDENTS DURING THE YEAR 1895 459

REPORT OF STATE SUPERVISOR OF OIL INSPECTION FOR 1894. BY N. J. HYDE.

INTRODUCTORY 462
STATISTICAL TABLES 463

REPORT OF STATE SUPERVISOR OF OIL INSPECTION FOR 1895. BY C. F. HALL.

INTRODUCTORY 468
LIST OF STATE DEPUTIES 468
STATISTICAL TABLES 469
PRODUCTION OF PETROLEUM IN INDIANA BY COUNTIES IN 1895 472

THE CRAWFISHES OF THE STATE OF INDIANA. BY W. P. HAY.

INTRODUCTION 476
THE GENUS CAMBARUS 476
SPECIFIC CHARACTERS 477
KEY TO SPECIES 478
DESCRIPTION OF SPECIES 481

THE NATURAL FUELS OF THE STATE.

The fuels of the State, Coal, Natural Gas and Petroleum, are valuable only for the stored energy which they contain. Energy and matter are the two things which comprise the Universe. Matter is anything which occupies space, as stone, water, gas. Energy is that which produces, changes or destroys motion in matter. In other words, it is the power of doing work. Energy exists in a number of different forms, as heat, light, electricity, gravitation, etc.

Since the year 1800, man has studied more closely than ever before both matter and energy, and as a result has made many important discoveries concerning them. The two greatest of these discoveries—which more than anything else will make the nineteenth century famous throughout all time—are embraced in those grand natural laws known as the "Law of the Indestructibility of Matter," and its correlative, "The Law of the Conservation and Correlation of Energy."

The first of these laws merely asserts that "*Matter can not be created, can not be destroyed;*" that the same amount, the same number of tons, pounds, ounces, yea, even grains, exists in the universe to-day as existed at the beginning of time. If the reader can bring himself to understand this great law and all that it embodies; to feel and know that every particle of soil, clay, stone or coal on, or in the earth has been formed from matter already in existence; that every living plant or animal is made up of matter which has existed for thousands, aye, millions of years, and which has been used over and over again in the structure of previously existing animals and plants, he will have gotten the main idea of this law, and be better able to understand many of the statements in the pages which are to follow.

The law of the conservation and correlation of energy asserts, "*That energy, like matter, can not be created, can not be destroyed, but that one form can be changed into any other form.*" In speaking of the natural fuels of the State, it is this law which we must ever bear in mind, as stored in these fuels is found the heat or energy which will drive the engines and turn the wheels for future generations. Man can invent no new forms of energy, nor can he produce a single iota of energy. He can only devise machines for transmuting or changing forms already existing into other and more available forms.

But the question naturally arises, how came this heat to be stored in the coal and other fuels? This question brings up another great truth which has become fully understood only in recent years, namely, that the *sun is the source of all the energy used in performing the work of the world.* From the sun comes heat and light which fall upon the grass and grain and trees of the earth and furnish the power or force necessary for their

growth. The plants use the heat and light to assimilate their food and promote their powers of vegetation, and at the same time they store up these forms of energy within their cells. Suppose, for example, that 1,000 calories (heat units) of heat are used in producing an ear of corn. When the ear is mature, that amount of heat, no more, no less, is stored up within its cells. This heat can be made available to perform work for man in two ways. First, by burning the corn in a furnace, when the heat will be freed and can be used to generate steam which in turn will cause wheels to revolve. Second, by feeding the ear of corn to a horse, in whose body the heat will be changed into muscular energy which can be exerted in turning wheels or in pulling loads. Or man himself can eat the corn, and the heat which is stored up in it will in his body be changed into muscular and mental energy. Thus the muscular force with which these words are written and the mental energy necessary to evolve the thoughts which they comprise, can be traced directly back to the sun's heat, which somewhere, in days gone by, fell upon and was stored up by plants, which directly or indirectly have formed the recent food of the writer. In other words we move muscles and think thoughts with the energy derived from sunlight.

The falling waters pulled by the force of gravitation down to the level of the sea, and on their way doing work for man by turning the wheels of many forms of machinery, were raised from the ocean by the heat of the sun; while the winds which bore those waters to the higher levels of the land also owe their power of movement to the unequal heating of the atmosphere by the sun's rays. Every ounce of steam and every current of electricity utilized by man is derived from or produced by the sun's heat stored in some kind of fuel.

Plants alone have the power of thus storing up the energy of the sun's light and heat. Animals are wholly lacking in this power, and can only utilize the energy so stored by plants. This fact has been well portrayed by Prof. Edward Orton, in the following words:

"The remarkable office of the vegetable cell is thus brought to light. It is a storer of power, a reservoir of force. It mediates between the sun, the great fountain of energy, and the animal life of the world. The animal can use no power that has not been directly or indirectly stored in the vegetable cell. This storage is forever going on. Of the vast floods of energy that stream forth from the great center of our system, an insignificant fraction is caught by the earth as it revolves in its orbit. Of the little fraction that the earth arrests, an equally insignificant part is used directly in plant growth. But the entire productive force of the living world turns on this insignificant fraction of an insignificant fraction."

Bearing in mind this great truth, we can better understand how in ages past the sun's light and heat were locked up in the cells of those

THE NATURAL FUELS OF THE STATE.

The fuels of the State, Coal, Natural Gas and Petroleum, are valuable only for the stored energy which they contain. Energy and matter are the two things which comprise the Universe. Matter is anything which occupies space, as stone, water, gas. Energy is that which produces, changes or destroys motion in matter. In other words, it is the power of doing work. Energy exists in a number of different forms, as heat, light, electricity, gravitation, etc.

Since the year 1800, man has studied more closely than ever before both matter and energy, and as a result has made many important discoveries concerning them. The two greatest of these discoveries—which more than anything else will make the nineteenth century famous throughout all time—are embraced in those grand natural laws known as the "Law of the Indestructibility of Matter," and its correlative, "The Law of the Conservation and Correlation of Energy."

The first of these laws merely asserts that "*Matter can not be created, can not be destroyed;*" that the same amount, the same number of tons, pounds, ounces, yea, even grains, exists in the universe to-day as existed at the beginning of time. If the reader can bring himself to understand this great law and all that it embodies; to feel and know that every particle of soil, clay, stone or coal on, or in the earth has been formed from matter already in existence; that every living plant or animal is made up of matter which has existed for thousands, aye, millions of years, and which has been used over and over again in the structure of previously existing animals and plants, he will have gotten the main idea of this law, and be better able to understand many of the statements in the pages which are to follow.

The law of the conservation and correlation of energy asserts, "*That energy, like matter, can not be created, can not be destroyed, but that one form can be changed into any other form.*" In speaking of the natural fuels of the State, it is this law which we must ever bear in mind, as stored in these fuels is found the heat or energy which will drive the engines and turn the wheels for future generations. Man can invent no new forms of energy, nor can he produce a single iota of energy. He can only devise machines for transmuting or changing forms already existing into other and more available forms.

But the question naturally arises, how came this heat to be stored in the coal and other fuels? This question brings up another great truth which has become fully understood only in recent years, namely, that the *sun is the source of all the energy used in performing the work of the world.* From the sun comes heat and light which fall upon the grass and grain and trees of the earth and furnish the power or force necessary for their

growth. The plants use the heat and light to assimilate their food and promote their powers of vegetation, and at the same time they store up these forms of energy within their cells. Suppose, for example, that 1,000 calories (heat units) of heat are used in producing an ear of corn. When the ear is mature, that amount of heat, no more, no less, is stored up within its cells. This heat can be made available to perform work for man in two ways. First, by burning the corn in a furnace, when the heat will be freed and can be used to generate steam which in turn will cause wheels to revolve. Second, by feeding the ear of corn to a horse, in whose body the heat will be changed into muscular energy which can be exerted in turning wheels or in pulling loads. Or man himself can eat the corn, and the heat which is stored up in it will in his body be changed into muscular and mental energy. Thus the muscular force with which these words are written and the mental energy necessary to evolve the thoughts which they comprise, can be traced directly back to the sun's heat, which somewhere, in days gone by, fell upon and was stored up by plants, which directly or indirectly have formed the recent food of the writer. In other words we move muscles and think thoughts with the energy derived from sunlight.

The falling waters pulled by the force of gravitation down to the level of the sea, and on their way doing work for man by turning the wheels of many forms of machinery, were raised from the ocean by the heat of the sun; while the winds which bore those waters to the higher levels of the land also owe their power of movement to the unequal heating of the atmosphere by the sun's rays. Every ounce of steam and every current of electricity utilized by man is derived from or produced by the sun's heat stored in some kind of fuel.

Plants alone have the power of thus storing up the energy of the sun's light and heat. Animals are wholly lacking in this power, and can only utilize the energy so stored by plants. This fact has been well portrayed by Prof. Edward Orton, in the following words:

"The remarkable office of the vegetable cell is thus brought to light. It is a storer of power, a reservoir of force. It mediates between the sun, the great fountain of energy, and the animal life of the world. The animal can use no power that has not been directly or indirectly stored in the vegetable cell. This storage is forever going on. Of the vast floods of energy that stream forth from the great center of our system, an insignificant fraction is caught by the earth as it revolves in its orbit. Of the little fraction that the earth arrests, an equally insignificant part is used directly in plant growth. But the entire productive force of the living world turns on this insignificant fraction of an insignificant fraction."

Bearing in mind this great truth, we can better understand how in ages past the sun's light and heat were locked up in the cells of those

plants which flourished in the swamps of the old carboniferous age. For thousands of years it accumulated within their stems and leaves and spores, and when, by the processes of nature, the plants were changed into coal it still remained, a most valuable heritage for future man.

In the same way the heat stored up in the natural gas and petroleum of the Trenton rocks came from the sun and was stored in the cells of those countless smaller forms of plants which grew on the margins or in the waters of the ancient Silurian seas. Animals used these plants for food, and so received the heat, and when they died, by a process of destructive distillation, the carbonaceous matter within their bodies was changed with its imprisoned heat into the gas and oil now so valuable as fuels.

The most important thing to remember in treating of these natural fuels is *that they are not being formed in our State to-day*. No coal, no gas, no oil, is being made in Indiana by nature's processes, either in the bowels of the earth or above it. Our present supply of each will never increase, but ever diminish. It is a great reservoir or deposit of reserve force upon which the people of the present generation are daily drawing without adding thereto. Like a bank account under the same conditions it is only a question of time until it will become exhausted.

COAL.—Seven thousand square miles, or one-fifth of the area of the State of Indiana is underlaid with coal. This area is found in the western and south-western part of the State, and ranges from ten to sixty miles in width. It extends from Warren County southward 150 miles to the Ohio River, where it is widest in extent, stretching across the counties of Vanderburgh, Warrick, Spencer, and part of Perry. Workable veins are found in nineteen counties in the area mentioned and thin outcrops occur in three additional ones. At least seven distinct veins of workable thickness occur in the State. These vary from three to eleven feet in thickness, and aggregate in a few places from twenty-five to twenty-eight feet. The area of greatest development of the seams is embraced in the counties of Clay, Sullivan, Greene, Daviess and Pike; though Parke, Vermillion, Vigo, Owen, Warrick and Spencer rank as close seconds.

The coals of the State are of two varieties, which in places merge into one another. These are the non-caking or block coal and the caking or bituminous coal. The former is one of the most valuable fuels found in the United States. It has a laminated structure and in the direction of the bedding lines it splits readily into thin sheets, but breaks with difficulty in the opposite direction. It can be mined in blocks as large as it is convenient to handle, whence its common name of "block coal." It is remarkably free from sulphur or phosphorus, and when burning it does not swell out nor does it form a cake by running together. It leaves no clinkers, the only residue after combustion being a small quantity of white ashes. Ordinary bituminous coals have to have their volatile constituents driven off and be changed into coke before they can be utilized in the making of iron products. The sulphur which they contain, if allowed to remain, would destroy the tenacity and malleability of the iron. Their tendency to cake or become packed under the weight of the overlying mass in the blast furnace prevents the free passage of the heat through all portions of the molten iron. The block coal, on account of its freedom from sulphur and phosphorus and its non-caking properties, can be used without coking and thus becomes a most valuable fuel for the blast furnace and the cupola of the iron founder.

For steam and household purposes it likewise has an unrivaled reputation. It burns under boilers with a uniform blaze that spreads evenly over the exposed surface, thus securing a more uniform expansion of the boiler plates. Its lack of sulphur also causes it to have but little detrimental effect upon the boilers, grates or fire boxes. In household grates it burns with a bright, cheerful blaze like hickory wood, making a very hot fire, which for comfort and economy can not be surpassed by any fuel except an abundant supply of natural gas.

The block coal area lies mainly in Clay, western Owen and southeastern Parke counties, though small deposits are found in other sections. A number of analyses of block coal from Clay County were made by Dr. G. M. Levette for the reports of the Geological Survey published in 1869 and 1870. The average of ten of these is given as follows:

Fixed carbon	56.83	
Ash	1.66	
Solid or coke producing matter		58.49
Gas	36.50	
Water	5.00	
Volatile		41.50

The following table shows also the average of the same ten in regard to the points mentioned:

Specific gravity	1.234
Pounds, weight of one cubic foot	77.16
*Units of heat	7983.00
*Steam value	1481.00

The bituminous or non-caking coals found in Indiana vary much in purity and character, but their average will compare favorably with that of those found in any other State. They are far more abundant than

*The "units of heat" show the number of pounds of water that one pound of coal will raise from 39° to 40° F. The "steam value" shows the number of gallons of water that one ton of coal will raise from 100° F. to steam, at atmospheric pressure. These computations were made by Dr. Levette and published in the Report of the Geological Survey for 1883.

the block coals, occupying an area of almost 6,500 square miles. Four workable seams are known, the maximum aggregate thickness of which is 20 feet, and the average aggregate thickness, over the greater part of the district, 11 feet.

The average analysis of ten of these coals, from Vigo, Daviess, Knox, Pike, Greene and Sullivan counties, is as follows:

Fixed carbon	53.89	
Ash	3.00	
Solid or coke-producing matter		56.89
Gas	38.67	
Water	4.4	
Volatile		43.07

The average of the other more important points is as follows:

Specific gravity	1.265
Pounds, weight of one cubic foot	77.85
Units of heat	8003.00
Steam value	1471.00

Comparing with these figures the following averages of four samples of Pittsburgh coal, as given in the Second Report of the Pennsylvania Geol. Survey:

Fixed carbon	59.46	
Ash	5.45	
Solid or coke-producing matter		64.91
Gas	32.57	
Water	1.06	
Volatile		33.63
Units of heat		7825.00
Steam value		1451.00

it will be seen that the average Indiana bituminous coal is slightly superior to the average Pittsburgh coal in heat and steam-producing power.

The Indiana coal fields are as yet in the infancy of their development, yet last year, according to careful statistics gathered by the State Mine Inspector, Mr. Robert Fisher, and published in another part of this volume, 4,202,084 tons were mined from them. It has been computed that a ton of good coal used in a good engine will perform the same amount of work as 1,300 horses in a day of ten hours. The amount mined in Indiana last year had, therefore, stored up within it and capable of utilization, power or energy equal to that exerted by 14,966,325 horses working 10 hours a day for an entire year.

The human mind can not conceive the vast amount of energy at present locked up in the coal fields of the State, nor place anything like an

accurate value upon it. The richest men of the nation to-day are those who have utilized the stored energy found in coal in years gone by, who have bought this energy by the ton at low prices, and either sold it in the form of manufactured articles at many fold its cost price, or used it in transporting, for hire, man and his products to the four corners of the globe.

But little has been done by the Department of Geology since 1878, towards the development of the coal fields of the State. Between 1869 and 1878, Prof. E. T. Cox, then State Geologist, issued seven reports which dealt largely with the facts concerning them, and in which their area, was fairly circumscribed, but no complete survey of the area as a whole was ever attempted.

Since 1878 thousands of bores have been put down to prove the presence of coal in workable quantities, and hundreds of shafts have been sunk to the veins which were close to railways. Much information has thus become available concerning the area covered by each seam, which, if properly gathered, could be used in the proper correlation of the seams in isolated areas.

Letters are constantly being received at the office of the State Geologist, asking for information concerning portions of the coal fields in which operations have been recently begun. To these no definite answers can be given, because no accurate survey has been made of such areas. The time has come when an accurate survey of the entire field is imperatively demanded, for the coal area of the State is bound to become its greatest manufacturing area. The cost of such survey, if conducted in a proper and thorough manner, has been carefully computed and found to be not less than $10,000 per year for two years. Other States with much smaller coal areas have given from $20,000 to $50,000 per year for four to six years. The last Legislature was asked to appropriate $8,000 per year for conducting a coal survey. It gave, instead, $3,800 for carrying on the entire work of the Department and State Museum. This sum became available in November, 1895, and in March, 1896, it is the intention of the Chief of the Department to begin a survey of the coal area, and to carry it on in such a manner and to such an extent as the small sum appropriated will permit.

The report of the State Mine Inspector, Mr. Robert Fisher, for the year 1895, is unusually full and complete. It shows that 664,851 more tons of coal were mined in 1895 than in 1894. Nearly 8,000 men are employed in the mines operating more than ten men, and if to these the number employed in the smaller mines be added, the total number will reach nearly 10,000.

A number of statistical tables are given, which are different from any that have appeared in previous reports.

the block coals, occupying an area of almost 6,500 square miles. Four workable seams are known, the maximum aggregate thickness of which is 20 feet, and the average aggregate thickness, over the greater part of the district, 11 feet.

The average analysis of ten of these coals, from Vigo, Daviess, Knox, Pike, Greene and Sullivan counties, is as follows:

Fixed carbon	53.89	
Ash	3.00	
Solid or coke-producing matter		56.89
Gas	38.67	
Water	4.4	
Volatile		43.07

The average of the other more important points is as follows:

Specific gravity	1.265
Pounds, weight of one cubic foot	77.85
Units of heat	8003.00
Steam value	1471.00

Comparing with these figures the following averages of four samples of Pittsburgh coal, as given in the Second Report of the Pennsylvania Geol. Survey:

Fixed carbon	59.46	
Ash	5.45	
Solid or coke-producing matter		64.91
Gas	32.57	
Water	1.06	
Volatile		33.63
Units of heat		7825.00
Steam value		1451.00

it will be seen that the average Indiana bituminous coal is slightly superior to the average Pittsburgh coal in heat and steam-producing power.

The Indiana coal fields are as yet in the infancy of their development, yet last year, according to careful statistics gathered by the State Mine Inspector, Mr. Robert Fisher, and published in another part of this volume, 4,202,084 tons were mined from them. It has been computed that a ton of good coal used in a good engine will perform the same amount of work as 1,300 horses in a day of ten hours. The amount mined in Indiana last year had, therefore, stored up within it and capable of utilization, power or energy equal to that exerted by 14,966,325 horses working 10 hours a day for an entire year.

The human mind can not conceive the vast amount of energy at present locked up in the coal fields of the State, nor place anything like an

accurate value upon it. The richest men of the nation to-day are those who have utilized the stored energy found in coal in years gone by, who have bought this energy by the ton at low prices, and either sold it in the form of manufactured articles at many fold its cost price, or used it in transporting, for hire, man and his products to the four corners of the globe.

But little has been done by the Department of Geology since 1878, towards the development of the coal fields of the State. Between 1869 and 1878, Prof. E. T. Cox, then State Geologist, issued seven reports which dealt largely with the facts concerning them, and in which their area was fairly circumscribed, but no complete survey of the area as a whole was ever attempted.

Since 1878 thousands of bores have been put down to prove the presence of coal in workable quantities, and hundreds of shafts have been sunk to the veins which were close to railways. Much information has thus become available concerning the area covered by each seam, which, if properly gathered, could be used in the proper correlation of the seams in isolated areas.

Letters are constantly being received at the office of the State Geologist, asking for information concerning portions of the coal fields in which operations have been recently begun. To these no definite answers can be given, because no accurate survey has been made of such areas. The time has come when an accurate survey of the entire field is imperatively demanded, for the coal area of the State is bound to become its greatest manufacturing area. The cost of such survey, if conducted in a proper and thorough manner, has been carefully computed and found to be not less than $10,000 per year for two years. Other States with much smaller coal areas have given from $20,000 to $50,000 per year for four to six years. The last Legislature was asked to appropriate $8,000 per year for conducting a coal survey. It gave, instead, $3,800 for carrying on the entire work of the Department and State Museum. This sum became available in November, 1895, and in March, 1896, it is the intention of the Chief of the Department to begin a survey of the coal area, and to carry it on in such a manner and to such an extent as the small sum appropriated will permit.

The report of the State Mine Inspector, Mr. Robert Fisher, for the year 1895, is unusually full and complete. It shows that 664,851 more tons of coal were mined in 1895 than in 1894. Nearly 8,000 men are employed in the mines operating more than ten men, and if to these the number employed in the smaller mines be added, the total number will reach nearly 10,000.

A number of statistical tables are given, which are different from any that have appeared in previous reports.

INTRODUCTORY.

The Department of Geology was primarily instituted to determine the location and extent of those natural resources of the State which are of economic importance, and to make known to the world at large the leading facts concerning their accessibility and value for commercial, agricultural or manufacturing purposes. A secondary duty which falls to the Department is the gathering and disseminating of accurate knowledge concerning the origin or formation of such resources, and the publishing of descriptions of such fossils and objects of natural history as are found to accompany them, or as are of general scientific interest.

Such information is presented to the public in annual reports issued by the chief or director of the Department. Five thousand copies of these reports are printed and distributed gratuitously to those persons who are especially interested in promoting the material development of the State, or who are seeking locations for the investment of capital. The present volume is the twentieth in the series of reports so ssued, and gives the general results of the work accomplished by the Department during the calendar year, 1895.

The natural resources of the State of Indiana, as of any other restricted area of the earth's surface, may be classified into two great groups. The first of these consists of those forms of matter which have stored within themselves potential energy in the form of heat, which may be set free by combustion and then be controlled by some device of man and used by him to perform work. Such natural resources are called *fuels*, the most important of which, as found in Indiana, are COAL, NATURAL GAS and PETROLEUM.

The second group of natural resources consists of those forms of matter which are devoid of any kind of stored energy which may be set free by combustion, but which are themselves used by man for varied and important purposes. The most valuable members of this group found in the State are SOILS, BUILDING STONES and CLAYS. Other and less important members are sands, iron ores, marls, etc.

Taking up separately these different resources, let us briefly notice, in this introductory part of the report, their general distribution, abundance and value.

THE NATURAL FUELS OF THE STATE.

The fuels of the State, Coal, Natural Gas and Petroleum, are valuable only for the stored energy which they contain. Energy and matter are the two things which comprise the Universe. Matter is anything which occupies space, as stone, water, gas. Energy is that which produces, changes or destroys motion in matter. In other words, it is the power of doing work. Energy exists in a number of different forms, as heat, light, electricity, gravitation, etc.

Since the year 1800, man has studied more closely than ever before both matter and energy, and as a result has made many important discoveries concerning them. The two greatest of these discoveries—which more than anything else will make the nineteenth century famous throughout all time—are embraced in those grand natural laws known as the "Law of the Indestructibility of Matter," and its correlative, "The Law of the Conservation and Correlation of Energy."

The first of these laws merely asserts that "*Matter can not be created, can not be destroyed;*" that the same amount, the same number of tons, pounds, ounces, yea, even grains, exists in the universe to-day as existed at the beginning of time. If the reader can bring himself to understand this great law and all that it embodies; to feel and know that every particle of soil, clay, stone or coal on, or in the earth has been formed from matter already in existence; that every living plant or animal is made up of matter which has existed for thousands, aye, millions of years, and which has been used over and over again in the structure of previously existing animals and plants, he will have gotten the main idea of this law, and be better able to understand many of the statements in the pages which are to follow.

The law of the conservation and correlation of energy asserts, "*That energy, like matter, can not be created, can not be destroyed, but that one form can be changed into any other form.*" In speaking of the natural fuels of the State, it is this law which we must ever bear in mind, as stored in these fuels is found the heat or energy which will drive the engines and turn the wheels for future generations. Man can invent no new forms of energy, nor can he produce a single iota of energy. He can only devise machines for transmuting or changing forms already existing into other and more available forms.

But the question naturally arises, how came this heat to be stored in the coal and other fuels? This question brings up another great truth which has become fully understood only in recent years, namely, that the *sun is the source of all the energy used in performing the work of the world.* From the sun comes heat and light which fall upon the grass and grain and trees of the earth and furnish the power or force necessary for their

growth. The plants use the heat and light to assimilate their food and promote their powers of vegetation, and at the same time they store up these forms of energy within their cells. Suppose, for example, that 1,000 calories (heat units) of heat are used in producing an ear of corn. When the ear is mature, that amount of heat, no more, no less, is stored up within its cells. This heat can be made available to perform work for man in two ways. First, by burning the corn in a furnace, when the heat will be freed and can be used to generate steam which in turn will cause wheels to revolve. Second, by feeding the ear of corn to a horse, in whose body the heat will be changed into muscular energy which can be exerted in turning wheels or in pulling loads. Or man himself can eat the corn, and the heat which is stored up in it will in his body be changed into muscular and mental energy. Thus the muscular force with which these words are written and the mental energy necessary to evolve the thoughts which they comprise, can be traced directly back to the sun's heat, which somewhere, in days gone by, fell upon and was stored up by plants, which directly or indirectly have formed the recent food of the writer. In other words we move muscles and think thoughts with the energy derived from sunlight.

The falling waters pulled by the force of gravitation down to the level of the sea, and on their way doing work for man by turning the wheels of many forms of machinery, were raised from the ocean by the heat of the sun; while the winds which bore those waters to the higher levels of the land also owe their power of movement to the unequal heating of the atmosphere by the sun's rays. Every ounce of steam and every current of electricity utilized by man is derived from or produced by the sun's heat stored in some kind of fuel.

Plants alone have the power of thus storing up the energy of the sun's light and heat. Animals are wholly lacking in this power, and can only utilize the energy so stored by plants. This fact has been well portrayed by Prof. Edward Orton, in the following words:

"The remarkable office of the vegetable cell is thus brought to light. It is a storer of power, a reservoir of force. It mediates between the sun, the great fountain of energy, and the animal life of the world. The animal can use no power that has not been directly or indirectly stored in the vegetable cell. This storage is forever going on. Of the vast floods of energy that stream forth from the great center of our system, an insignificant fraction is caught by the earth as it revolves in its orbit. Of the little fraction that the earth arrests, an equally insignificant part is used directly in plant growth. But the entire productive force of the living world turns on this insignificant fraction of an insignificant fraction."

Bearing in mind this great truth, we can better understand how in ages past the sun's light and heat were locked up in the cells of those

plants which flourished in the swamps of the old carboniferous age. For thousands of years it accumulated within their stems and leaves and spores, and when, by the processes of nature, the plants were changed into coal it still remained, a most valuable heritage for future man.

In the same way the heat stored up in the natural gas and petroleum of the Trenton rocks came from the sun and was stored in the cells of those countless smaller forms of plants which grew on the margins or in the waters of the ancient Silurian seas. Animals used these plants for food, and so received the heat, and when they died, by a process of destructive distillation, the carbonaceous matter within their bodies was changed with its imprisoned heat into the gas and oil now so valuable as fuels.

The most important thing to remember in treating of these natural fuels is *that they are not being formed in our State to-day*. No coal, no gas, no oil, is being made in Indiana by nature's processes, either in the bowels of the earth or above it. Our present supply of each will never increase, but ever diminish. It is a great reservoir or deposit of reserve force upon which the people of the present generation are daily drawing without adding thereto. Like a bank account under the same conditions it is only a question of time until it will become exhausted.

COAL.—Seven thousand square miles, or one-fifth of the area of the State of Indiana is underlaid with coal. This area is found in the western and south-western part of the State, and ranges from ten to sixty miles in width. It extends from Warren County southward 150 miles to the Ohio River, where it is widest in extent, stretching across the counties of Vanderburgh, Warrick, Spencer, and part of Perry. Workable veins are found in nineteen counties in the area mentioned and thin outcrops occur in three additional ones. At least seven distinct veins of workable thickness occur in the State. These vary from three to eleven feet in thickness, and aggregate in a few places from twenty-five to twenty-eight feet. The area of greatest development of the seams is embraced in the counties of Clay, Sullivan, Greene, Daviess and Pike; though Parke, Vermillion, Vigo, Owen, Warrick and Spencer rank as close seconds.

The coals of the State are of two varieties, which in places merge into one another. These are the non-caking or block coal and the caking or bituminous coal. The former is one of the most valuable fuels found in the United States. It has a laminated structure and in the direction of the bedding lines it splits readily into thin sheets, but breaks with difficulty in the opposite direction. It can be mined in blocks as large as it is convenient to handle, whence its common name of "block coal." It is remarkably free from sulphur or phosphorus, and when burning it does not swell out nor does it form a cake by running together. It leaves no clinkers, the only residue after combustion being a small quantity of white ashes. Ordinary bituminous coals have to have their volatile constituents driven off and be changed into coke before they can be utilized in the making of iron products. The sulphur which they contain, if allowed to remain, would destroy the tenacity and malleability of the iron. Their tendency to cake or become packed under the weight of the overlying mass in the blast furnace prevents the free passage of the heat through all portions of the molten iron. The block coal, on account of its freedom from sulphur and phosphorus and its non-caking properties, can be used without coking and thus becomes a most valuable fuel for the blast furnace and the cupola of the iron founder.

For steam and household purposes it likewise has an unrivaled reputation. It burns under boilers with a uniform blaze that spreads evenly over the exposed surface, thus securing a more uniform expansion of the boiler plates. Its lack of sulphur also causes it to have but little detrimental effect upon the boilers, grates or fire boxes. In household grates it burns with a bright, cheerful blaze like hickory wood, making a very hot fire, which for comfort and economy can not be surpassed by any fuel except an abundant supply of natural gas.

The block coal area lies mainly in Clay, western Owen and southeastern Parke counties, though small deposits are found in other sections. A number of analyses of block coal from Clay County were made by Dr. G. M. Levette for the reports of the Geological Survey published in 1869 and 1870. The average of ten of these is given as follows:

Fixed carbon	56.83	
Ash	1.66	
Solid or coke producing matter		58.49
Gas	36.50	
Water	5.00	
Volatile		41.50

The following table shows also the average of the same ten in regard to the points mentioned:

Specific gravity	1.234
Pounds, weight of one cubic foot	77.16
*Units of heat	7983.00
*Steam value	1481.00

The bituminous or non-caking coals found in Indiana vary much in purity and character, but their average will compare favorably with that of those found in any other State. They are far more abundant than

*The "units of heat" show the number of pounds of water that one pound of coal will raise from 39° to 40° F. The "steam value" shows the number of gallons of water that one ton of coal will raise from 100° F. to steam, at atmospheric pressure. These computations were made by Dr. Levette and published in the Report of the Geological Survey for 1883.

the block coals, occupying an area of almost 6,500 square miles. Four workable seams are known, the maximum aggregate thickness of which is 20 feet, and the average aggregate thickness, over the greater part of the district, 11 feet.

The average analysis of ten of these coals, from Vigo, Daviess, Knox, Pike, Greene and Sullivan counties, is as follows:

Fixed carbon	53.89	
Ash	3.00	
Solid or coke-producing matter		56.89
Gas	38.67	
Water	4.4	
Volatile		43.07

The average of the other more important points is as follows:

Specific gravity	1.265
Pounds, weight of one cubic foot	77.85
Units of heat	8003.00
Steam value	1471.00

Comparing with these figures the following averages of four samples of Pittsburgh coal, as given in the Second Report of the Pennsylvania Geol. Survey:

Fixed carbon	59.46	
Ash	5.45	
Solid or coke-producing matter		64.91
Gas	32.57	
Water	1.06	
Volatile		33.63
Units of heat		7825.00
Steam value		1451.00

it will be seen that the average Indiana bituminous coal is slightly superior to the average Pittsburgh coal in heat and steam-producing power.

The Indiana coal fields are as yet in the infancy of their development, yet last year, according to careful statistics gathered by the State Mine Inspector, Mr. Robert Fisher, and published in another part of this volume, 4,202,084 tons were mined from them. It has been computed that a ton of good coal used in a good engine will perform the same amount of work as 1,300 horses in a day of ten hours. The amount mined in Indiana last year had, therefore, stored up within it and capable of utilization, power or energy equal to that exerted by 14,966,325 horses working 10 hours a day for an entire year.

The human mind can not conceive the vast amount of energy at present locked up in the coal fields of the State, nor place anything like an

accurate value upon it. The richest men of the nation to-day are those who have utilized the stored energy found in coal in years gone by, who have bought this energy by the ton at low prices, and either sold it in the form of manufactured articles at many fold its cost price, or used it in transporting, for hire, man and his products to the four corners of the globe.

But little has been done by the Department of Geology since 1878, towards the development of the coal fields of the State. Between 1869 and 1878, Prof. E. T. Cox, then State Geologist, issued seven reports which dealt largely with the facts concerning them, and in which their area was fairly circumscribed, but no complete survey of the area as a whole was ever attempted.

Since 1878 thousands of bores have been put down to prove the presence of coal in workable quantities, and hundreds of shafts have been sunk to the veins which were close to railways. Much information has thus become available concerning the area covered by each seam, which, if properly gathered, could be used in the proper correlation of the seams in isolated areas.

Letters are constantly being received at the office of the State Geologist, asking for information concerning portions of the coal fields in which operations have been recently begun. To these no definite answers can be given, because no accurate survey has been made of such areas. The time has come when an accurate survey of the entire field is imperatively demanded, for the coal area of the State is bound to become its greatest manufacturing area. The cost of such survey, if conducted in a proper and thorough manner, has been carefully computed and found to be not less than $10,000 per year for two years. Other States with much smaller coal areas have given from $20,000 to $50,000 per year for four to six years. The last Legislature was asked to appropriate $8,000 per year for conducting a coal survey. It gave, instead, $3,800 for carrying on the entire work of the Department and State Museum. This sum became available in November, 1895, and in March, 1896, it is the intention of the Chief of the Department to begin a survey of the coal area, and to carry it on in such a manner and to such an extent as the small sum appropriated will permit.

The report of the State Mine Inspector, Mr. Robert Fisher, for the year 1895, is unusually full and complete. It shows that 664,851 more tons of coal were mined in 1895 than in 1894. Nearly 8,000 men are employed in the mines operating more than ten men, and if to these the number employed in the smaller mines be added, the total number will reach nearly 10,000.

A number of statistical tables are given, which are different from any that have appeared in previous reports.

Mr. Fisher has visited many of the mines twice, or even three times, and has seen to it that all things needed to insure, in the fullest degree, the safety and comfort of the men employed therein were provided by the operators.

PETROLEUM.—Within the past two years the production of petroleum has attained enormous proportions in Indiana. The area in which the oil is found has steadily increased, and to-day comprises parts of Adams, Wells, Huntington, Grant, Blackford, Jay, Randolph and Delaware counties. In addition, a few flowing wells are in operation in the city of Terre Haute, but repeated drilling has failed to locate any extensive field in Vigo County.

During the year 1895, 2,711 new oil wells were completed in the State. Of these 754 were dry. The aggregate initial output of the productive wells finished during the year was 46,342 barrels daily. If this initial output had kept up for a year, it would have resulted in the enormous total of 16,914,830 barrels. But, as noted below, the spouting of an oil well soon ceases, and the average output is thereby rapidly diminished.

In the following table will be found a statement of the production of petroleum in Indiana from 1889 to 1895, inclusive:

Production of Petroleum in Indiana, from 1889 to 1895.

	1889.	1890.	1891.	1892.	1893.	1894.	1895.
Total production (barrels of 42 gallons)	33,375	63,496	136,634	698,068	2,335,293	3,688,666	4,380,000
Total value at wells of all oils produced, excluding pipage	$10,881	$32,462	$54,787	$260,620	$1,050,882	$1,774,260	$3,109,800
Value per barrel	$0.32⅝	$0.51⅛	$0.40	$0.37	$0.45	$0.48	$0.71[*]

The probabilities are that the area of territory productive of oil will continue slowly to spread to the west and south until it finally embraces the greater part of the area at present yielding natural gas. This has been, in general, the history of other gas and oil fields, and there is no known reason why the one of Indiana should prove an exception. The oil, on account of its much greater specific gravity, underlies the gas in the area where the two are found together. As the pressure of the gas gradually decreases on account of a diminution of the supply, the hydrostatic pressure of the oil in time overcomes that of the gas, and a spouting or flowing well of oil results.

How much oil there is beneath the surface of Indiana is a question that no man can answer. How long the supply will last depends wholly upon its amount and the average daily or yearly drain therefrom. Suffice it

[*] This is the average of the 36 different prices at which oil sold during the year.

to say *that the supply is limited and will never be increased.* The age of a productive oil well in the United States does not generally exceed five years and is very often much less. A spouting oil well does not continue to gush forth for many weeks if allowed to flow freely. It soon degenerates into a flowing well and then into a pumping well, whose production dwindles away and finally ceases to be remunerative, so that unless new wells are continually being developed the output must fall off and finally cease entirely. However, there is no danger of the supply beginning to fail in Indiana for some years to come, as it has as yet been drawn upon for too short a time. True, some of the older wells have ceased to yield, but for every one so abandoned a dozen productive ones have been opened up; and this will continue to be the case until the total oil area, which can only be circumscribed by the future use of the drill, is fully developed.

NATURAL GAS.—During the past nine years natural gas has done more to advance the material interests of the State of Indiana than any other two resources within her bounds. Millions of dollars of capital have been invested within the gas field and thousands of people have flocked thereto attracted by ready employment at good wages. As a consequence both the wealth and population of the area in which gas has been found have increased many fold.

Originally that area embraced part of or all of seventeen counties lying northeast of the center of the State and comprised on the whole about 5,000 square miles. On account of the encroachment of salt water and petroleum, this area has become gradually reduced until to-day the main gas field contains an approximate area of 2,500 square miles. This, however, is larger than has ever been possessed by any other State in the Union.

The average initial or rock pressure of the entire field in 1889 was 325 pounds to the square inch. To-day, according to careful measurements made during the past season by Mr. J. C. Leach, the State Natural Gas Supervisor, it is 230 pounds to the square inch over the main field. There is no doubt but that one-half of the supply has been nearly or quite exhausted, and as there can be no increase of it, the pressure will decrease more rapidly in the future than in the past. How long the supply will last no man can tell. Too many varying factors, as the daily amount necessarily consumed for fuel and heat, the different pressures at which salt water and petroleum overcome the gas pressure—and more than aught else—the future percentage of waste, enter into the consideration of such a question. If the waste could be entirely shut off, the supply in the heart of the field, where much undeveloped territory has been held in reserve, would probably last for a number of years. It is in cities like Indianapolis and Richmond, which receive their supply through pipe lines, that the diminution in pressure is most noticeable; and there is no doubt but that their supply will become completely exhausted some time before that of the cities which lie wholly within the field. For the main facts concerning the present condition of the field the reader is referred to the report of Mr. Leach for the year 1895, which is found in another part of the present volume. No report for 1894 was submitted to me by the former inspector, Mr. E. T. J. Jordan.

RESOURCES OTHER THAN FUELS.

SOILS.—Indiana is preëminently an agricultural State. Her soils constitute by far the most valuable of her natural resources. More people are dependent upon them for a livelihood than upon all the rest of her resources and manufacturing establishments combined. Ranking in area of square miles but thirty-fourth among the forty-five States of the Union, the census of 1890 shows that she stood second in the production of wheat,* seventh in the production of corn, and eighth in the value of her live stock.

This magnificent showing is due to two things: first, the excellent, average fertility of her soils; second, the high degree of intelligence manifested by her farming population, in the cultivation of the soils.

In the production of any cereal nothing new is created, but forms of matter already existing in the earth, air and water are utilized by the growing plant. Taking wheat, for example, besides the carbon, hydrogen and oxygen, which make up the greater bulk of the straw and grain, and which are abundant enough in the air and water, potash, nitrogen, phosphoric acid, magnesia, lime, sulphur, chlorine and silicon are absolutely essential constituents. If any *one* of these is lacking in the soil, or is present in a form not available by the wheat roots, the plants will not flourish and the soil will be worthless for wheat production. Such a soil may, in most cases, be made to produce a crop of grain by adding to it the constituent which is lacking, but if this can not be done except at a prohibitory cost, or one at which more fertile ground can be procured, the soil may be regarded as "worn out" or barren.

The drift soils, which cover the northern and central portions of Indiana, derived, as they were, from various primary and igneous rocks in the far north—ground fine and thoroughly mixed as they were by the onward moving force of a mighty glacier—are usually rich in all the above named necessary constituents of plant food and do not require a large annual outlay for artificial fertilizers as do the soils of southern Indiana, over which the drift of the glacial period did not extend.

While the methods of soil cultivation in vogue in Indiana are, perhaps, above the average, too many of the farmers of the State never stop to

*Illinois was first, with 37,389,000 bushels; Indiana, a very close second, with 37,318,000 bushels.

consider that in the growth of a crop absolutely nothing is created. With no knowledge of chemistry they do not understand that the tons of grain, straw and stalks, which their fields produce, are only transformations of materials which existed in other forms either in the earth or air.

Too many of them go on year after year, taking from their fields all the products, grain, straw, and everything, and giving nothing back. They do not realize that those vast freights of grain and meats which tax our means of transportation to the utmost, are great streams of the elements of fertility flowing from their fields to the towns and cities of this continent, and to the marts of the Old World never to return. They never think of that law of compensation which asserts that we can not supply in one place without removing from another. As a consequence their lands become, after a time, deficient in one or more of the necessary grain constituents and therefore comparatively worthless. Then they allow those lands to remain idle or else begin to buy fertilizers in a reckless manner, knowing nothing of the chemical composition of that which they buy, or whether it contains the elements of plant food which are lacking.

Thus hundreds of thousands of dollars are annually spent for fertilizers which are worthless to the persons buying them, because they do not contain the constituents needed; and thousands of acres of land are left untilled, or are tilled at a loss, because of a lack of a certain element of fertility which is unknown to the owner and therefore not supplied by him.

Constituting as they do the most valuable of our natural resources it can be readily seen that the study of the origin, distribution and constituents of the soils of the State falls naturally to the Department of Geology. Many facts concerning them which would be eminently useful to the farmer are now entirely lacking, and can be gained only by a careful and systematic study of the soils in the different localities of the State. Complete analyses of soils from every county, showing the proportions of phosphates, nitrates and other necessary elements of vegetation, should be made. From them the farmer could determine what constituent of his soil, if any, is deficient, and could supply the same in suitable quantities and in an available form. From them, also, it would be possible to specify the localities where the different staple crops could be most advantageously grown, instead of compelling the farmers to learn the peculiarities of their lands by experiments which necessarily consume time and exhaust the soil. While such a study of the soils would undoubtedly result in a large annual increase of the agricultural products of the State, it can not be undertaken until the Legislature becomes more generous in the appropriation allotted to carry on the work of the Department of Geology.

BUILDING STONES.

LIMESTONES.—No State in the Union possesses better stone for building purposes than Indiana. The oölitic limestone from Lawrence, Monroe and other counties has long been noted among architects for its strength and durability. It is of a uniform rich gray color and close texture, and on account of the ease with which it can be quarried, sawed and dressed for builders' use it can be sold with profit for a less sum per cubic foot than any other stone in America.

The best grades of it contain 97 per cent. of carbonate of lime, which is practically indestructible by ordinary atmospheric influences. It contains of iron oxide and alumina, two of the most damaging constituents of such stone, less than one per cent., thus showing a remarkable degree of purity.

The average crushing strength of twelve samples of tool dressed oölitic stone, as determined by Maj.-Gen. Q. A. Gilmore for the Board of State House Commissioners in 1878, was 7,857 pounds per square inch, while that of four samples of sawed oölitic stone was 12,675 pounds per square inch.

The best deposits of the oölitic stone are found in a narrow strip of territory extending from Greencastle, Putnam County, to Salem, Washington County, a distance of 110 miles. The width of this strip varies from three to ten miles, and the stone throughout its full length is found very close to the surface.

Since the building of the Court House and the State House at Indianapolis from this stone its use for public and private buildings has steadily increased, especially in the East and South. A number of the private residences of the richer citizens of New York City have been recently constructed from it, while its use in such important public buildings as the Custom House at New Orleans, the Auditorium at Chicago, and many court houses in the counties of adjoining States has served to bring it more prominently before the attention of the public. During the year 1895 the quarries in operation in the oölitic district had an output of more than 15,000,000 cubic feet, the most of which was shipped to points outside of Indiana.

While much has been published in the previous reports of this Department concerning the oölitic limestone, it has been of a general nature, and no careful detailed survey of the limited area in which it is found has ever been made. It is my intention to begin such a survey as soon as the season opens in 1896, and to have prepared an accurate map showing the exact limits of the more valuable deposits found therein.

Besides the oölitic limestones a number of crystalline limestones or so-called "Indiana marbles" are found in the State. These admit of a fine polish and make most handsome mantels and other interior decorations; while some of them are close textured, strong and durable enough to be well fitted for masonry. One of the most valuable of these deposits is found in the southern part of Fayette County, and belongs to Hon. J. N. Huston of Connersville. Others occur on Pipe Creek in Miami County, and at English, Crawford County.

Besides the above, which are limestones largely or almost wholly composed of calcium carbonate, numerous quarries are worked in the State in which magnesium carbonate is a leading constituent of the stone. These are found, for the most part, in the eastern half of the State, and belong to the Silurian formations. As a rule they are not building stones of a high grade. They are darker than the oölitic stone and more apt to crumble after years of exposure, as they contain a larger percentage of iron oxide. The magnesia present also causes them to blacken and disintegrate more or less readily, especially in cities where the atmosphere contains large amounts of sulphurous fumes derived from the burning of soft bituminous coals. However, much of the magnesium limestone quarried in Indiana will compare favorably both in texture and durability with many of the stones used for building purposes in other States.

SANDSTONES.—"The Carboniferous Sandstones of western Indiana," is the title of an extensive paper which was prepared for the present volume by Mr. T. C. Hopkins, the chief assistant to the State Geologist.

Mr. Hopkins is a trained geologist, who for a number of years was connected with the Geological Survey of Arkansas, and prepared the volume on the building stones of that State. He is a specialist in that particular subject, and his report on the sandstones of western Indiana, will be found thorough, accurate and valuable.

He spent the season of 1895 in the field, and made a personal investigation of the leading outcrops and worked quarries of sandstone in the area shown on the two map sheets accompanying his report. The Conglomerate or Millstone Grit, in which these sandstones mostly occur, is a great formation lying at the base of the Coal Measures of the State. It is wholly useless to look for coal east of the eastern horizon of this formation.

Mr. Hopkins found that in a number of localities the sandstones comprising the so-called Conglomerate are valuable commercial stones, easily worked and of great durability. In several places, notably at St. Anthony, Dubois County; Bloomfield, Greene County, and Portland Mills, Parke County, the stone is of a handsome brown color, and compares favorably in appearance with the brown sandstones of the Lake Superior region which are so much used for the fronts of business blocks in Chicago, Milwaukee, and other cities of the Northwest.

One use to which this brown sandstone is peculiarly well fitted is for the lintels and cornices above the windows and doors of those buildings whose fronts are composed of dry pressed brick. Where limestone is used for the lintels, the rain, dashing against it, is sure to dissolve out a small portion of the stone which flows down over the brick and gives them a mouldy, streaked appearance. Where the brown sandstone is used no such streaking is seen on the brick beneath the windows and archways. The color of the sandstone also harmonizes better with that of the brick than does that of the limestone.

Large quarries of buff and gray sandstone have been in successful operation for a number of years at Attica, Williamsport and Riverside, and at Cannelton, on the Ohio River. Other localities where such stone can be quarried to advantage are noted in the report of Mr. Hopkins, and it is hoped that his report, being by far the most complete which has ever been issued on the sandstones of Indiana, will do much toward leading to the development of these sandstones, which form an important but hitherto much neglected resource of the State.

WHETSTONE AND GRINDSTONE ROCKS.

It is perhaps not generally known that Indiana is the second State of the Union in the production of whetstones and grindstones. The fine-grained silicious rock found in Orange and Martin counties has long been used for such purpose, but no detailed survey of the region in which it is found, or report on the industry, has been heretofore made.

Mr. E. M. Kindle, formerly Assistant Professor of Geology in the State University, was employed for the season of 1895 to make such a survey, and his report of the work accomplished, together with an accurate map of the region, is included in the present volume.

Full details concerning the various deposits of stone (found in the area mapped) suitable for manufacturing into abrasive materials are given, together with the methods of manufacture as carried on at the present time. A lack of capital and railway facilities has hitherto undoubtedly kept this industry from assuming those proportions which the abundance and quality of the raw material would seem to merit.

CLAYS.

Among the most valuable of the undeveloped resources of the State are her clay deposits. In one form or another they are found in every county, but the largest and most valuable ones occur in the western and southwestern parts of the State, where the coal measures exist, for the coal measures of the State are preëminently its clay measures. Every seam of coal is normally underlain with a bed of fire clay, and above the coal there are almost always beds of shale. These coal shales a few years ago were thought to be worthless, but experiment has proven that they are excellently adapted to the making of paving brick, roofing tile, sewer pipe and many similar products. In Ohio, where forty-four paving brick factories turned out 298,000,000 paving brick in 1894, 80 per cent. of the best grades were made of the carboniferous shales which ten years ago were wholly unused.

So much of the field season of 1895 as could be spared from routine office work was devoted by the State Geologist in person to a detailed study of the different clays of the coal bearing counties, and to an investigation of the methods used in the clay working factories found within their bounds. The results of such study and investigations are incorporated in the accompanying paper, entitled, "The Clays and Clay-working Industries of the Coal-bearing Counties of Indiana." Complete analyses of twenty-eight clays have been made especially for this paper by Profs. W. A. Noyes and Robert Lyons, and will be found in a table at the end of the second chapter. From them much can be learned concerning the fitness of the clays for especial products.

The clay-working industries of the State have grown apace in the last five years, and full statistical tables showing their present state of development are given on later pages. No hesitation is felt in prophesying that within the next ten years they will become the leading manufacturing industries of western Indiana. Raw material and fuel, both of excellent quality, are found associated together in enormous quantities in many places which are accessible to transportation; and where the three elements of fuel, raw material and railways are thus combined, capital in time is sure to locate and utilize the natural resources. The larger clay industries already in existence in the vicinity of Brazil, Terre Haute and other places, are all of them flourishing; the demand for their products in many instances being greater than the possible supply. They have proven by practical experience that the shales and underclays of the coal measures are in every way fitted for manufacturing purposes. The analyses given in this report but add additional testimony.

Most of these clay industries, as well as the larger coal, stone, natural gas and oil interests, are owned by outside capital. The people of the State, for some unknown reason, seem reluctant to invest money in the resources found within her bounds. Outside capitalists have no such reluctance, and their investments have almost universally proved to be winning ones. While much capital is thus brought into the State, thereby increasing its total wealth, the profits, which in time aggregate far larger sums, are removed as fast as made. With local capital invested the profit would remain and the wealth upon which the taxes are based would increase much more rapidly.

One of the chief beneficial effects which the development of the clay-working industries will bring about, will be the increasing of the available amount of coal in the State. Many seams now thought to be too thin to work will be utilized in connection with the associated shales and fire clays. The minimum thickness of a workable seam of coal will, therefore, be greatly reduced, and many veins which have long been allowed to pass unnoticed will be mined with profit.

IRON ORES.—Limonite or bog iron ore ($2\ Fe_2O_3+3H_2O$), and siderite or kidney iron ore ($FeCO_3$), are found abundantly in several counties of Indiana. The former occurs notably in Greene, Martin and Perry counties, and in the swamps of the Kankakee region; the siderite in all of the coal bearing counties. Experience has proven, however, that these ores are too silicious to compete with the rich beds of hematite of Missouri, Tennessee and Georgia. As a proof of this it is only necessary to state that of fourteen blast furnaces which have been erected in the State in the past, not one is in operation at the present. Most of them have long since gone to ruin, and of those still standing the last one went out of blast in 1893.

SANDS.—White sand, suitable for glass making, occurs in quantity in the vicinity of Pendleton, Madison County; Montpelier, Blackford County, and Lapel, Hamilton County. Near Salem, Washington County, and Centerton, Morgan County, are found large deposits of a fine grade of moulder's sand, suitable for foundry use. Sand suitable for building purposes occurs in all parts of the State.

MARL.—The use of marl for making hydraulic and Portland cement, and as a disinfectant and deodorizer, is constantly on the increase. Deposits of this resource which are close to railways will undoubtedly prove of much value in the future. The largest at present known are found in the vicinity of Silver Lake, Dekalb County; Lime Lake, Steuben County, and near South Bend and North Liberty, St. Joseph County.

OTHER MINERALS AND ORES.—With the exception of small quantities of drift gold, in the form of minute grains and scales, which are found in the sands and gravel beds along the streams of Brown, Morgan and other counties near the southern limit of the drift area, no gold, silver or other precious metal occurs in the State. Much money has been foolishly spent and time wasted by people who have thought otherwise; but they have ever had their labor for their pains.

In many of the northern counties small pieces of "black jack" or zinc blende, galena or lead sulphide, and native copper ore, are occasionally found, and give rise to much local excitement and speculation. It is needless to say that the specimens of copper and lead were also brought in by the drift or by the Indians; and the blende, while possibly of native origin, is utterly valueless. In almost every county one also hears tales of reputed silver and lead mines, which in the days of long ago were secretly worked by the Indians. Many well informed people yet believe these tales, and have spent days in fruitlessly searching after imaginary mines, where enough silver may be had to pave the streets of their native towns, or where lead ore exists without limit.

While Indiana is thus lacking in the precious and other useful metals, her deposits of coal, clay, stone, natural gas and petroleum are far more valuable, and will in time bring more wealth into the State than if, instead of them, rich mines of gold and silver had been found within her bounds. Higher grades of labor and more stable industries are based upon such resources, for few, if any, large factories utilize gold and silver in quantity as a manufacturing resource.

NATURAL HISTORY.

While this Department was primarily originated to gather and disseminate information concerning the mineral resources of the State, the existing flora and fauna present interesting scientific problems which to the earnest student of nature are ever worthy of careful study. Valuable papers on the flora of different counties and on the reptiles and fishes of the State, have appeared in some of the previous reports. In this one is found a paper on "The Crawfishes of Indiana," by W. P. Hay, formerly a resident of Irvington, Ind., now Professor of Natural History in the Central High School, Washington, D. C. Professor Hay has made for a number of years a special study of the crustaceans of Indiana, and the present paper embodies the results of a large amount of original research.

The crawfishes inhabit every running stream and lake in the State. They form much of the food of the larger fishes, and are themselves most valuable scavengers, so that the paper, dealing as it does in part with questions of distribution and habit, has an economic as well as a purely scientific side. The students of our colleges and high schools interested in zoölogy will, I am sure, welcome the appearance of such a paper. In it every species of crawfish inhabiting the State is carefully described, and the descriptions are preceded by analytical keys and accompanied by drawings of the more important specific characters, so that with a little careful attention the identity of any species at hand can be readily determined.

THE STATE MUSEUM.

The museum connected with this Department has become a center of attraction to many of the people of the State who come to Indianapolis. An average of three hundred persons visit it each day, and its educating effect can hardly be overestimated. The time of the State Geologist during the winter season, when field work can not be done, is largely taken up in connection with work pertaining to it. A thorough rearrangement of its contents on an accurate scientific basis is being made, and a catalogue prepared, so that future incumbents of the office may know what ought to be therein. According to the 12th Annual Report of the Department, issued in 1882 (p. 7), there were then 100,000 specimens in the museum. If that statement be accurate many of them have since disappeared, for no more than 60,000 are on hand to-day. No record of additions or catalogue of contents having been kept, it is impossible to determine the locality or history of many of the specimens which are unlabeled, and much of their value is therefore lost.

The museum should contain, in addition to specimens of archæology and paleontology, examples of the different objects of Natural History found within the State. Many of our birds and mammals are rapidly becoming extinct, and while to-day they can be procured at a nominal sum, in ten years they can not be had at any price. A number of mounted birds and a large collection of fishes and reptiles were secured the past season, and it is the intention to add to the collection of such objects as rapidly as the means available will permit.

The case-room for specimens is exhausted, and the new ones received have to be stored in out-of the-way places until a sum is appropriated for additional cases. Those provided for the battle-flags are wholly inadequate for the proper display and preservation of the flags. The latter are so crowded that the ones belonging to the different regiments can scarcely be distinguished.

OFFICE WORK.

One object of the founders of the Department of Geology was undoubtedly to establish a bureau where official information could be secured at all times by the citizens of Indiana, or by the public at large, concerning the resources of the State. During the year 1895 more than 1,900 letters of inquiry concerning such resources have been answered by the Geologist. In addition to this, information was given concerning the character and value of 840 specimens of minerals and objects of Natural History which were sent to him for examination. Persons who seek advice from the Department are often restrained from sinking thousands of dollars in useless search for minerals, gas and oil in localities where there is not one chance in a thousand of finding the object sought.

A PRELIMINARY REPORT ON THE CLAYS AND CLAY INDUSTRIES OF THE COAL-BEARING COUNTIES OF INDIANA.

BY W. S. BLATCHLEY.

CHAPTER I.

GENERAL USES OF CLAYS—DEFINITION OF CLAYS—PROPERTIES OF CLAYS—ORIGIN AND CLASSIFICATION OF CLAYS—IMPURITIES OF CLAYS.

No mineral resource of the earth has been longer used or has been made into such varied products for the benefit of the human race as clay. Found in all countries, easily obtained, and, when moistened, readily molded into any shape which the fancy can invent, it is no wonder that prehistoric man, emerging slowly from that animal stage in which for thousands of centuries he had existed, made early use of it. To his undeveloped mind no better form of amusement probably presented itself than that of dabbling in mud and molding it into fantastic shapes—just as on the borders of many a pond or stream "mud pies" are made by the youthful progeny of the nineteenth century. Some of his rude products—sun-dried—became permanent, were used by him as drinking vessels, and so begat in his crude mind an impression of their usefulness. He began to fashion them, not for amusement but for use, and the clay industry of the world had begun. From such a beginning, into what enormous proportions has it grown!

Clay products, when properly made and cared for, are among the most lasting works of man. Wind or rain, frost or fire, has little effect upon them. The most ancient remains of man's industry are the pieces of pottery vessels picked up on the sites of his former habitations, or removed from his burial mounds. The oldest buildings on earth are those made of sun-dried brick. From these rude vessels, relics of man's first handiwork, to the delicate and costly china ware of our shops—from the adobe walls on the plains of Persia and Mexico to the magnificent fronts of pressed brick and terra cotta of our present cities—what steps of human progress—what proofs of man's advancement in the art of clay working!

GENERAL USES OF CLAY.

No natural material can be so easily and cheaply made into the finished product as clay. It enters more largely into the necessities of our every day life than does any other mineral resource; and the ultimate value of its products are greater than of any other, except iron. The following are some of the uses to which materials made of clay are put in Indiana:

1. DOMESTIC.—Utensils, porcelain ware, china ware, granite or ironstone ware, yellow ware, earthen ware, fire kindlers, etc.

2. STRUCTURAL.—(*a.*) For buildings: Brick, common, front or pressed, ornamental, hollow, glazed; terra cotta, roofing tile, drain tile, door-knobs, puddling. (*b.*) For roadways: Vitrified brick.

3. AGRICULTURAL.—Drain tile, soil tile, soil tempering, barn flooring.

4. HYDRAULIC STRUCTURES.—Water conduits, reservoir lining, sewer pipe, "stone" pumps.

5. SANITARY ENGINEERING.—Granite ware, urinals and water-closet bowls, earthen ware, sewer pipe, absorbent brick, drain tiles, ventilating flues.

6. INDUSTRIAL ARTS.—China clay, chemists' crucibles and other apparatus, wall and writing paper filling, refractory clay, lime, cement and pottery kilns, puddling hearths, reverbatory and other smelting furnaces, glass pots, assaying furnaces, gas retorts, stove and furnace linings, saggars, plugs, models, alums, etc.

7. ORNAMENTAL AND ÆSTHETIC USES.—Tiling, ornamental pottery, terra cotta decoration, artists' molding clay, base for retaining pigments.

8. IMITATIVE USES.—Food adulterants, paint adulterants.*

The above materials, to the value of more than twenty millions of dollars, are annually used in our State, while heretofore less than five millions of dollars' worth have been produced within her bounds. Yet, with the exception of some of the clays used in the making of encaustic tile, porcelain and china ware, Indiana contains, as I shall endeavor to show in a subsequent chapter, the raw material in abundance to manufacture every one of the above mentioned articles.

DEFINITION OF CLAYS.

The term clay is, in popular language, given to a large number of widely different materials. To most persons it calls to mind any soft, structureless, earthy matter, which, when moistened with water, will become plastic and sufficiently firm to be fashioned into any desired form.

*Adapted from a table given by Robert T. Hill, Vol. VIII, Mineral Resources of United States, 1891, 475.

To the manufacturer it may be either the above or an artificial mixture of several or many constituents, ready to be turned, molded or pressed, and then burned or baked to the required hardness.

To the chemist and geologist it has a far wider meaning including all rocky material whose chief constituent or "clay base" is composed of the three elements,* silicon, aluminum and oxygen, joined in chemical union, and holding more or less water in combination with themselves. To this clay-base has been given the name "kaolin" or "kaolinite," and its chemical formula has been found to be:

$$Al_2O_32SiO_2+2H_2O$$

or

$$Al_2Si_2O_7+2H_2O,$$

which shows that it is composed of two parts of aluminum, two of silicon, and seven of oxygen chemically combined and united with two parts or molecules of water.

When pure its percentage composition is as follows:

Silica (SiO_2)	46.3
Alumina (Al_2O_3	39.8
Water (H_2O)	13.9

In other words kaolin is what chemists call a hydrated silicate of alumina; *i. e.*, a silicate of alumina combined with water. This kaolin may, and often does, as we shall hereafter see, exist in an almost pure state, but in most cases it is found mixed with numerous other minerals, such as free silica or sand, oxides of iron, lime, mica, magnesia, etc., in greater or less proportions.

To these mixtures (as well as to the pure kaolin itself) the general term "*clay*" rightfully belongs, whether they appear in incoherent masses, as those to which the name is most commonly given, or in a more consolidated and finely laminated condition—the so-called "*shales*;" or in the still more thoroughly consolidated "*slates*." Finally, from the above, it may be readily perceived that the greater the amount of kaolin or clay-base in the mixture the purer is the clay. Still, the name of clay is given to the mixture if it contains no greater amount than 10 per cent. of the kaolin.

*For those who have little or no knowledge of chemistry I have thought it best to give here a definition of the word "element," as it will be hereafter used on numerous occasions. An *element* is one of the seventy primary forms of matter which make up the universe. It is a substance which has never been separated into anything simpler. Two or more elements united together form a *compound*. There are millions of compounds, but only seventy elements. For example: Wood is a compound, which in the chemical laboratory can be separated into three substances, carbon, hydrogen and oxygen, but no man has as yet been able to separate carbon, hydrogen or oxygen into anything simpler than themselves. Hence they are elements. The seventy elements bear the same relation to the compounds as the twenty-six letters of the English language bear to its four hundred thousand words. Or, to state it still differently, the elements form the alphabet of the universe.

PROPERTIES OF CLAY.

The value of clay for the purposes to which it is put depends upon certain essential and characteristic properties which we shall now briefly consider. One of the most important of these is

PLASTICITY.—It is this property which causes clay when wet with water to become a tough, pasty mass, readily capable of being fashioned into any form by the hands or molds; and, when so fashioned, to retain its shape while being carried to the drying room or kiln. Very few other minerals or artificial compounds possess this peculiar and important property. Particles of iron, sandstone or limestone are almost wholly non-plastic, and, when wet, will not cohere to any great extent.

The cause of the plasticity of clays is, as yet, a mooted question among scientists. Many of the purer residual clays, *i. e.*, those which have been formed in the place where they are now found, are almost non-plastic. When examined under the microscope such clays appear to be largely made u] small, six-sided crystalline plates or scales, arranged in bundles and surrounded by numerous, smaller unattached scales. When such clays are ground fine, and the crystalline structure of the plates in part destroyed, they become much more readily plastic. A re-examination under the glass then shows that the plates which still retain their crystalline form are imbedded in a matrix made up largely of the particles of those which have been destroyed.

Now our natural clays, which are most plastic, are sedimentary, or those which have been carried by water or ice to the places they now occupy. In their journeyings they have been ground and reground, their crystalline structure destroyed, and their particles reduced to a very fine condition and thus rendered more susceptible to cohesion with particles of water. It is true many of them may have been consolidated into shales and slates, but most of these by repeated grinding are again rendered plastic. *The property of plasticity, therefore, appears to depend largely upon the absence of crystalline structure in the clay-base or kaolinite, and the fineness to which the particles mixed with this have been reduced.* A further proof of this is seen in the effect produced by "weathering." Clays which are mined in autumn and exposed to rain and frost throughout the winter have the crystalline structure of their kaolin more or less broken up by alternate freezing and thawing. Their degree of fineness is at the same time increased, rendering them more highly plastic, and therefore more readily moulded into any desired shape.

That *plasticity*, to a certain extent, depends upon the presence of combined water in the clay-base, is shown by the fact that when heated to redness and this water driven off, the clay loses its plastic quality. Brick dust or burned clay may be ground fine and moistened, but unless mixed with some unburned plastic material the particles will not cohere.

Some clays possess too great a degree of plasticity and are called "lean" clays. This fault can be easily remedied by mixing with a more non-plastic clay. On the other hand, many common brick clays which are too non-plastic for use, have from earliest times been moulded with straw to give them sufficient tenacity to be handled while being placed in the kiln.

A second important property of clay is

INSOLUBILITY.—The better grades of clay are not affected by any acid or other chemical. If, for example, a few drops of either muriatic (hydrochloric) or sulphuric acid be poured upon a piece of iron or limestone, a bubbling or effervescence will take place, and, if sufficient acid be used, the iron or stone will soon wholly disappear. No such action occurs with kaolin. When, however, a clay is very impure, containing a large percentage of lime, carbonate of iron, or other deleterious matter, the same effervescence is seen when the acid is applied.

As many of the products made of clay are liable in time to be brought directly or indirectly in contact with injurious chemicals, it will be readily seen that this property of insolubility, which is possessed by the raw material and transmitted to the manufactured product, is a most valuable one. It often prevents their destruction or enables them to be put to many uses in which utter freedom from chemical action is demanded.

A third and indispensable property of clay is

INFUSIBILITY OR REFRACTORINESS.—Kaolin and many of the purer grades of fire-clay can be subjected without fusing or melting to the highest heat obtainable in the practice of metallurgy. This can be said of but few other minerals, chief among which is quartz or silica, which is one of the leading impurities mixed with kaolin to form the different kinds of clays.

This fire resisting or refractory property is one of the most remarkable and valuable which clays possess. Upon it depends their use for making that long list of materials, which of necessity must be subjected to intense heat, such as crucibles, gas retorts, glass pots, reverbatory furnaces, etc.

But it is only the purer clays, as kaolin, or kaolin mixed with silica (the so-called fire-clays) that are infusible. When other substances commonly found in sedimentary clays, such as lime, potash, iron, etc., are present, a comparatively low temperature will bring about a fusion or melting. Chemical changes will result and new compounds, chief among which are complex artificial silicates, will be formed. To all such substances whose presence tends to bring about the melting of refractory material the general name of "*fluxes*" is given. Named in the order of their power to cause the fusion of kaolin the leading fluxes are potash, soda, iron, lime and magnesia. The presense of a small amount of one or more of these is sufficient to destroy the refractory property of an otherwise excellent fire-clay.

The infusibility of kaolin is chiefly due to the same property being possessed by its constituents, silica and alumina. Each can be melted only in the flame of the oxy-hydrogen blow-pipe. Combined with kaolin to form the fire-clays is almost always a large per cent. of free silica or sand, which is nothing more than small particles of quartz. This is the only impurity that can be mixed with kaolin without lessening its property of infusibility. In all the better grades of fire-clays a large percentage of this free silica is present. The Montezuma fire-clay, which has a wide reputation throughout Indiana and adjoining States for fire-resisting qualities, contains a total of 83.4 per cent. of silica; while some refractory materials are manufactured from quartzose rock, which is finely ground and then mixed with a small amount of plastic fire-clay to give it tenacity. But few large deposits of either kaolin or fire-clay free from fluxing impurities are known to exist; and such of these as are readily accessible are of great commercial value.

Another property of clay, and the last one to be here mentioned, is the power which it possesses of *hardening* when subjected to heat. No especial name has been given to this property yet its importance can scarcely be over-estimated. Without it an article fashioned from clay would be only so much stiff mud, which on exposure to rain or frost would soon crumble to dust on account of its porosity and attraction for moisture. Any clay which is plastic enough to be molded into shape can be baked and thereby made to become hard, solid, and stone-like in appearance.

The first change taking place in the clay when heated is the driving off of the water which has been added to it to make it soft and plastic. This should be done "so slowly as to allow all of this moisture to escape as vapor before the clay becomes heated above the boiling point of water, for the generation of steam would of course tend to destroy the structure which has been imparted to the clay and which is important to keep."* After this hygroscopic water has been driven off the heat may be increased more rapidly, until at about 1000° F. the ware will begin to shrink and lose weight on account of the loss of the combined water in the clay-base or kaolinite.

Thereafter the clay "will grow more hard and dense and more impervious to water, until finally, if the heat be stopped at the right point, it will have become practically impervious and very hard, strong and tough. Clay in this condition is a new chemical compound composed of a mixture of all its bases (metals) combined with all its acids, forming a mineral as nearly indestructible as any known. Small bits of pottery made in the

* Orton, Edw., Jr., Geol. of Ohio, VII, 80.

earliest times of pre-historic man come down to us as fresh and unaltered by the centuries of exposure as they were when made. Records made in hard burnt clay are imperishable, except to animate force. If the heat be continued above this most favorable point the clay begins to deteriorate in some of its qualities. It may grow harder but less strong, or it may become spongy and vesicular like lava, or it may melt into a fragile glass, but whatever the change, it is a retrogression. What the temperatures are at which these various results are obtained, depends wholly upon the nature and composition of the clay under treatment. Some clays require only a low heat to develop their best qualities, others demand the highest heats attainable in the practice of metallurgy." *

THE ORIGIN AND CLASSIFICATION OF CLAYS.

All clays, soils and sands, are, in the first place, derived from the decomposition or breaking up of different kinds of rock. I say "are derived," for the silent processes of nature to-day, as in past geological ages, are grinding rocks into clays and recementing and hardening clays into rocks. There was a time when the surface of the earth was formed of rocks and rocks only, but various natural agencies began and kept in constant action processes of slow decay, and clays, soils and sands were formed, and afterwards, as we shall see, carried as sediments into ancient seas.

The rocks that formed that first crust of the earth were largely or wholly igneous in their nature, *i. e.*, they were rocks which had been acted upon by great heat, and had not been deposited in stratified layers by water. The most common of them were the granites, gneisses and syenites. As kaolin, which is the base of all clays, may be formed from any of these three kinds of rocks, the process being essentially the same, I shall take granite and try and make plain the origin of kaolin from it.

Granite is an igneous rock composed of three minerals, quartz, mica and feldspar. *Quartz* is the most abundant of all minerals, and in one form or another comprises fully 25 per cent. of the crust or hard surface of the earth. It is composed of two elements, silicon and oxygen, united in the proportions of one part of the former to two of the latter, the chemical formula being SiO_2. The chemical name of this compound is silica and it is wholly insoluble in rain water or ordinary acids. Of *mica*, the second mineral constituent of granite, it is necessary to say nothing in this connection, except that it, like quartz, is not acted upon or decomposed by rain water.

But to *feldspar*, the third mineral found in granite, especial attention should be given since it is the source from which all kaolin, is supposed

* Orton, *loc. cit.*, 76.

to have been derived. Feldspar is the common name given to a group of very complex minerals. The most abundant of these is *orthoclase*, the kind of feldspar usually found in granite. It is composed of four elements, silicon, oxygen, aluminum and potassium, and its chemical formula is K_2O, Al_2O_3, $6SiO_2$, showing that it is what chemists ca a double silicate of potash and alumina. In other words it is a silicate of potash chemically combined with a silicate of alumina—the former being soluble in rain water—the latter, as we have seen in another connection, wholly insoluble. Granite, then, may be regarded as composed of particles of insoluble quartz united to particles of insoluble mica by a cement of feldspar which is partly soluble and partly insoluble.

Now the geologist recognizes three great natural agencies as constantly acting upon the surface of the earth. One is *igneous* or the agency of internal heat, which in some place is always pushing a portion of the earth's surface upward. The second agency, and the most important one, as far as the formation of clay is concerned, is the *atmosphere*. This is composed of three gases, oxygen, nitrogen and carbon di-oxide, and in addition to these, watery vapor. Of these the nitrogen is inert or non-active and has nothing to do with the formation of clay. The oxygen, carbon di-oxide and water, either separately or combined, are universal solvents and, in time, will cause the crumbling of the hardest rocks. The oxygen unites with certain elements or minerals in the rocks to form new compounds. The particles of these compounds cohere or unite less closely than the particles of the rock before the compounds were formed, and in time lose their cohesion and fall apart. A somewhat similar action is seen when a leaden bar is melted and then stirred until all its particles are brought in contact with the oxygen of the air. A new compound, lead oxide, wholly unlike the original bar lead, is formed, which is easily reduced to a powdered state.

The watery vapor in the air when cooled, condenses and falls as rain. As it passes downward it gathers unto itself a part of the gaseous carbon di-oxide of the atmosphere and unites with it to form rain or carbonated water. When this falls upon the granite, already softened to a certain extent by the oxygen of the air, it percolates it and the carbon di-oxide (CO_2) leaves the water and unites with the potash (K_2O) to form potassium carbonate (K_2CO_3). This, being a very soluble substance, is soon washed out by the water, thus destroying the cement which held the particles of quartz and mica together. The granite, therefore, crumbles apart and there results from it a mass of *kaolin* (the insoluble silicate of alumina of the feldspar), mixed with quartz particles or sand, and numerous scales of mica. Thus is kaolin the basis of all clays, formed from granite or any rock of which feldspar is a constituent.

The clay materials resulting from the decay of feldspar may be broadly classified into two great groups—residual clays and sedimentary clays.

RESIDUAL CLAYS

are those which have remained on or very near the spot formerly occupied by the rocks from which they are derived. If these rocks contained much feldspar, or but little mica, and were covered before their decay by some permeable material such as conglomerate sandstone through which the water could easily pass, large beds of comparatively pure kaolin were formed. Such deposits are called residual rock kaolins and are among the richest and purest known to man. The kaolin deposits of Lawrence and Martin counties, Indiana—of whose especial origin more will be said hereafter—are examples of such residual clays.

If, on the other hand, the mica be present in abundance, or should there be quantities of such impurities as hornblende or iron pyrites in the rock, the resulting residual clay will be largely mixed with oxides of iron derived from the hornblende, mica or pyrite, and will be a mere red brick clay of little or no value. Thus it happens that although many localities are known where granite has decayed in great abundance, but few of them yield large deposits of a good quality of kaolin.

South of what is known as the drift area in Indiana—of which more anon—there occurs a surface clay which is also residual, being derived from the decay of the underlying limestone or sandstone rocks. During thousands of years the rainfall penetrating these rocks has carried with it well known solvent agencies derived from the atmosphere and from the vegetation on the surface. Attacking the rocks, these solvents have borne away the several ingredients which they were competent to dissolve and have left the rest behind. The result has been the production of well disintegrated earth or soil at the surface merging into clay and partly decomposed rock below. For the most part this clay is in essentially the same state as when separated from the primitive crystalline, feldspathic rocks, as the decay of the limestone or sandstone has only restored it to the condition in which it was when deposited with the sediments of which they were formed. It is composed mainly of a mixture of kaolinite, oxides of iron, and sand combined in varied proportions, the kaolinite being the silicate of alumina that was disseminated in small particles through the limestones or sandstones at the time of their formation. This residual surface clay is free from those minute angular fragments of foreign rocks which occur so commonly in most glacial or drift clays. It is never stratified like the latter sometimes are, and its texture is more homogeneous or alike throughout. For these reasons its quality for manufacturing purposes is far superior to that of most of the surface drift clays of northern Indiana.

SEDIMENTARY CLAYS

are those which have been removed from their place of origin and redeposited in water. This removal has been brought about by water either in its liquid or solid form; for the third great natural agency acting upon the surface of the earth is known as "*aqueous*" or the agency of water. This has to do, however, with the distribution rather than the origin of clays and soils. Gentle rains and earth-born torrents, little trickling rills and strong streams are ever at work tearing down the clays from every slope where feldspathic rocks have decayed and bearing them away to lower levels. While being carried onward the clay-base or kaolin, comparatively pure at starting, becomes mingled with many impurities, such as the remains of decayed limestones, oxides of iron, etc. It, as well as these impurities, are at the same time washed and ground fine by the action of the flowing water until finally the entire mixture is deposited as a bed of fine sedimentary clay at the bottom of river, lake or sea, perhaps one, perhaps a thousand miles from the home of its mother rock. Since the first rain-fall upon the primitive crust of the earth this process of disintegration and transportation of clay by water has been going on, and on it will continue until the end of time, for the forces of nature are never ceasing in their action.

As a result vast beds of sedimentary clays are found wherever lakes or seas have at some former period covered a portion of the surface of the earth. In many cases these clays have by pressure been consolidated and hardened into "*shales*." The chemist recognizes no difference between a shale and a clay, and the geologist distinguishes them only by a thin lamination, or capability of being separated into layers, which is present in the shale and absent in the clay and which is generally due to the former having been deposited intermittently in deep, still water.

Shales are classified and named according to the character of the chief impurity which is mixed with their clay-base. Thus we have silicious shales, micaceous shales, calcareous shales, bituminous shales, etc. These differ widely in their relative hardness and in the degree of plasticity which they show when ground fine and mixed with water. In general, however, they as well as the soft sedimentary clays are highly plastic on account of the constant grinding and washing which they have undergone previous to their final deposition in water.

The beds of sedimentary clay now found upon the surface of the earth are very few of them identical with those first formed after the decay of the primitive crystalline rock. That igneous force which somewhere is ever pushing the bottom of the sea upward, long ago raised those first shale beds into dry land. Rain and frost again caused their decay, and again did the agency of flowing water mix and grind and bear their particles to the bottoms of new seas and lakes. No one knows, or can ever know, how often these successive changes of elevation, disintegration, erosion and deposition have taken place in the ages past; but the clay-base in the materials of our buildings and roadways of to-day, would, if traced backwards, lead us through many a geologic change to the granites and gneisses of the old archæan times.

We shall find in Chapter II, that the most important sedimentary clays of the coal measures are the different shales which overlie the seams of coal, and farther information concerning their origin will be given there. Underlying each coal seam is almost always a bed of "*fire-clay*"—a form of sedimentary clay usually richer in kaolin and silica and poorer in the fluxes than the shales. This fire-clay had its origin in the same manner as did the shales, but its freedom from lamination is a proof that it was deposited in shallower water. Its relation to the overlying coal seam plainly shows that it once formed the soil which supported that luxuriant plant growth from which the coal was in time derived. Although the general name of "fire-clay" is applied indiscriminately throughout the coal-bearing counties to all the under-clays of the coal seams, yet but few of them, properly speaking, are refractory clays of a high grade. The majority of them contain so great a percentage of the fluxes that they fuse readily at even moderate temperatures. The origin of all is, however, practically the same, and a farther classification, based on their more valuable properties, will be given in the next chapter.

Along the lowlands of the Ohio and Wabash Rivers and their larger tributaries are found, at intervals, enormous beds of "*alluvial*," or river-bottom clays. These are sedimentary clays of the most recent times and owe their origin either to deposition in the eddies of those streams, or to the slow accumulation of the clayey sediment during the annual overflows of the areas which they occupy. Oftentimes they alternate with strata of sand or even gravel. In some places they are 30 to 50 feet in depth and free from pebbles or coarse impurities of any kind. They are usually very plastic owing to the presence of more or less lime and iron oxides in a finely divided state. In Ohio similar clays have been used for several years in the manufacture of paving material, but in Indiana their only use heretofore has been in the making of ordinary building brick.

One other form of sedimentary clay remains to be mentioned—namely, the so-called "*drift-clays*" or "*hard-pans*," which are the characteristic surface clays of northern Indiana. From the shales and fire-clays which, in many places, underlie them, they differ widely in the amount of lime and other foreign constituents which they contain. This difference is mainly due to the fact that they were transported to and deposited in their present resting places, not by water in the liquid form, as were the shales and fire-clays, but by a great glacier or moving sea of ice which, thousands of years ago, flowed slowly over the greater portion of our State, grooving and planing the surface of the solid rocks, strewing for hundreds of miles in its track beds of clay and sand and gravel—pushing before it the accumulated soils and clays of centuries, and mixing, transporting and changing them to such an extent as to well nigh destroy their separate characteristics and greatly increase the difficulty of their proper classification.

The climate of the region to the north of us was similar, at that time to that of Greenland to-day, or even cooler. The snow, ever falling, never melting, accumulated there in one vast field of enormous thickness. Near the bottom of this mass a plastic, porous sort of ice was gradually formed from the snow by the pressure from above. This ice took upon itself a slow, almost imperceptible, motion down into the valleys to the southward. As it moved thus onward, dirt bands were formed along its margins; stones and great masses of partly decayed rock and clay from hillsides and jutting cliffs rolled down upon it, and were carried on and on, until, by the melting of their icy steed, they were dropped upon the clean-swept surface rock below. In this way all the beds of so-called "drift clays" were accumulated where they lie.

In Indiana they form the surface clays north of a line drawn approximately from the southeastern corner of the State to the Wabash River at a point midway between Terre Haute and Evansville. South of this line the surface clays are, for the most part, the variety of residual clays mentioned above. Transported and deposited as they were, it is no wonder that the drift clays are too impure for any use but the making of ordinary brick and drain tile, and oftentimes they contain too much lime even for this purpose, numerous analyses showing the presence of as high as 40 per cent. of calcareous material. This is due to the grinding up and mixing with the clays much of the surface limestones over which the glacier passed, as the erosion of that epoch not only removed and commingled the previously formed residual deposits, but planed away the country over a vast area to a greater depth than had been reached by any previous decay. These eroded limestones and the clays with which they were mixed were many of them ground into impalpable powder and deposited before a subsequent decay could take place, so that, as has been well said, "the drift clays are, many of them, rock flour, and not, as are the residuary clays, the products of rock rot."*

Summing up the last few pages we find, therefore, that, based either upon the relation of their present location to their place of origin, or the manner of their transportation and deposition, we have the following classification of our Indiana clays:

*Chamberlain, T. C.—Sixth Ann. Rept., U. S. Geol. Surv., p. 249.

- CLAYS.
  - *Residual.* Remaining on or near the place of their origin.
    - *Rock Kaolins* of Lawrence and adjoining counties.
    - *Surface Clays* of the driftless area of southern Indiana.
  - *Sedimentary.* Removed from their place of origin and deposited in water.
    - Transported by water.
      - Ancient or paleozoic.
        - *Shales.* Laminated owing to deposition in deep water.
        - "*Fire-Clays.*" Unlaminated; deposited in shallow lakes or marshes.
      - Recent.
        - *Alluvial.* Deposited by our present rivers and streams.
    - Transported by ice.
      - *Drift Clays.* The surface clays of northern and central Indiana.

Based upon the relative proportions of clay-base and fluxes which they contain, one of the most recent and best classifications of clays is that given by Prof. Edward Orton (Seventh Rep., Ohio Geol. Surv., 1894, p. 52), as follows:

		Uses—
High Grade Clays	1. Kaolin	Manufacture of fine ware.
	2. China clay	" " "
	3. Porcelain clay	" " "
	4. Fire clay (hard)	Refractory materials.
	5. Fire clay (plastic)	" "
	6. Potters' clay	Earthenware, etc.

		Uses—
Low Grade Clays	1. Argillaceous shale	Paving block, etc.
	2. Ferruginous shale	Pressed brick, etc.
	3. Silicious clays	Paving block, sewer pipe, etc.
	4. Tile clays	Roofing tile, draining tile.
	5. Brick clays	Pressed brick, ornamental brick.
	6. Calcareous shale	Common brick, etc.

Concerning the above classification, Prof. Orton says: "The first division comprises all clays and shales that contain in conjunction with not less than 50 per cent. of kaolin base little else but finely divided silica. The amounts of the fluxing elements are in all cases small, rarely aggregating as much as 5 per cent., and generally falling below 3 per cent. Oxide of iron constitutes much the largest single element of these fluxes. In almost every case the potash is low."

"The second division includes all ordinary clays and shales. They may range in kaolin base from 10 to 70 per cent, but they always carry a notable percentage of the fluxing elements. The alkalies generally make 2 to 5 per cent., while lime, magnesia and iron add two or three times as much more. Coarse sand and rock fragments often make a conspicuous part also. These low qualities of the clay more frequently result from a surplus of fluxing element than from a deficiency in kaolin base."

IMPURITIES OF CLAYS.

Although much has been already said, in a general way, concerning the impurities found in clays, it is thought best to make in this connection, a more detailed mention of some of them, together with their effect upon the value of the clay for manufacturing purposes.

As already noted, anything other than the silicate of alumina forming the clay base may be considered as an impurity. The impurities most commonly found in clay are as follows: Silica; various compounds of iron; lime and magnesia; the alkalies, potash and soda; titanic acid, and organic matter. True, other substances sometimes occur, such as pebbles of crystalline rocks, ores of copper and zinc, compounds of sulphur, etc., but they are found so rarely that the mere mention of them will be sufficient. Free or uncombined

SILICA (SiO_2)

in the form of sand (disintegrated quartz) is found, to some extent, in all clays. The purest residual clays contain it in minute quantities, and some of the sedimentary clays have as high as 40 to 50 per cent. mingled with their clay-base, so that it is often difficult to tell where a sandy clay ends and a clayey sandstone or "freestone" begins. Although classed as an impurity, yet in the making of most clay products this free silica is an absolutely essential part of the raw material; since its presence prevents that warping, shrinking and cracking while drying which is sure to take place in the made-up product when too great a percentage of pure kaolin is present. In many cases where the clay is too rich in alumina, sand has to be artificially mixed with it before it can be used. Whenever so mixed, the natural adhesiveness, plasticity and strength of the clay are reduced; while its brittleness, and usually its refractory property are increased.

Of the clay impurities above mentioned, the

COMPOUNDS OF IRON

are, next to silica, the most common and the most important. Pure iron does not exist free in nature, but its compounds are very abundant. Among those occurring *uncombined* in clays are the two oxides—the proto or ferrous oxide (FeO); and the per, sesqui, or ferric oxide (Fe_2O_3); also the carbonate ($FeCO_3$); the sulphide (FeS_2), and the sulphate ($FeSO_4$). In addition to these many chemists believe that most every clay has, *chemically combined* with its kaolin or clay-base, a hydrated per-oxide of iron ($2Fe_2O_3+3H_2O$), the two together forming a complex double salt of iron and alumina.

The presence of iron oxides has much to do with the colors of clays, both in the raw and the burned state, for iron is one of the great coloring agents in nature. Compounds of iron cause the green color of grass and leaves, the bright red color of the blood of animals, and the darker red of some soils, clays and sandstones. The proportionate amount of uncombined iron oxides present has little to do, however, with the color of the clay in either its burned or raw state. Experience, time and again, has proven that no one can tell by looking at a clay, or even by analyzing it, what color will be produced in it by heat. In general, however, it may be stated that the finer the particles of these oxides are, and the more evenly they are disseminated through the clay, the more uniform and certain will be the color. For this reason chemists believe that the complex double salt of iron and alumina, mentioned above, has much to do with the ultimate color of burned clays, as, of necessity, the iron oxide in this is more thoroughly and evenly distributed throughout the raw material. If the oxides occur *free* in small grains or nodules, a chemical change will be caused in them by heat, and they will be apt to form black specks, scattered irregularly through the body of the ware instead of coloring it evenly throughout. The color to which a clay burns is, moreover, determined to a large extent by the different degrees of heat to which it is subjected in the kilns.

Iron oxides, besides imparting a color to clay products, also often act as fluxing agents. This is especially noticeable in those shales and surface clays which contain from 5 to 15 per cent. of these oxides. Such clays fuse and vitrify at much lower temperatures than others which are similar in every respect, except in the quantity of iron they contain.

Pyrites, or iron sulphide (FeS_2), is probably the most harmful of all the compounds of iron occurring in clays. It is usually in the form of small crystalline nodules or grains, or in concretionary ball-like masses, one to three inches in diameter, and having the surface oxidized into a brownish shell. These are popularly known as "sulphur balls," and are found in some of the shale deposits of the Indiana coal measures. When present in any quantity pyrites causes the clay constituents to fuse at a temperature much below that at which the proper vitrifaction takes place.

Sulphate of iron, or copperas ($FeSO_4$), is often produced in clay deposits containing pyrites by the oxidation of the latter. Its presence may be known by the astringent, inky taste which it imparts to the clay, and usually by the presence of a white efflorescence upon the surface. Like the pyrites, it is a very damaging constituent, rendering the clay in which it is found comparatively worthless.

Iron carbonate, or siderite ($FeCO_3$), is also a quite common mineral in the shale beds of the Indiana coal measures. It is usually found in the form of either lenticular or kidney-shaped nodules, which contain more or less clayey matter, and are known as iron kidneys or clay ironstone. They vary much in size, and often occur in layers at regular intervals apart, making it easy for the clay miner to separate them. If too large a proportion of them are ground up with the shale they increase too highly the percentage of iron, and so reduce the fusing temperature. Otherwise they are comparatively harmless, as under the influence of heat the carbonate is decomposed into ferrous-oxide and the gaseous carbon di-oxide ($FeCO_3 = FeO + CO_2$).

Some residual and almost all sedimentary clays contain

LIME AND MAGNESIA,

one or both, in small but persistent quantities. The best clays contain less than two per cent. of these substances—though for some purposes clays, containing as high as 25 per cent. of lime, may be utilized. When present, lime and magnesia usually occur either as silicates or carbonates—more commonly the latter. Like the oxides of iron their degree of harmfulness depends largely upon their physical condition. If finely divided and intimately mixed throughout the clay they are less injurious than if in the form of small grains or pebbles of limestone. When in the latter condition, as they commonly are in the glacial or surface drift clays, the carbonate of lime ($CaCO_3$), when the clay is burned, loses carbon di-oxide (CO_2). This leaves calcium oxide or quick lime (CaO), which has a very strong attraction for water. When the finished product is exposed to the air each of these particles of quick lime will absorb moisture, and expand, bursting off pieces of the ware and so causing a defect or shallow pit in its surface.

When present in quantity, and in a finely divided state, lime and magnesia not only act as fluxes, but also combine to a certain extent with the oxides of iron and give a peculiar whitish or cream colored tint to the finished products. For this reason many of the more recent sedimentary clays—as those found along the margins of our present lakes and rivers

—although rich in iron, produce a light colored instead of a red brick. Such bricks are made at South Bend and Michigan City, Indiana, and at Milwaukee, Wisconsin.

As already stated (p 27) the alkalies,

POTASH AND SODA,

rank among the leading fluxing impurities found in clays. They occur in small quantities in almost all clays, probably as silicates in the form of undecomposed particles of mica or feldspar. These fuse at a lower temperature and unite more readily with the clay-base than do any of the other impurities (iron, lime or magnesia) above mentioned. Their presence in any quantity in clays desired for refractory purposes is, therefore, most pernicious. On the other hand, where vitrified products are to be made, it is necessary that some of these fluxes be present, that they may cause the clay constituents to begin to fuse and combine at the proper temperature; and so bring about that peculiar, non-porous, "vitrified" condition which is so characteristic of all non-absorbent clay products.

The analyses of ten shales from Ohio and six from Indiana, which are used in the manufacture of vitrified brick or sewer pipe, show an average composition of about 13 per cent. of all fluxes and 84 per cent. of kaolin and sand. Probably from 8 to 10 per cent. of the fluxes would serve all necessary purposes, but a less proportion would leave the material unvitrified and porous and therefore of too absorbent a nature for use. As potash and soda are the most powerful fluxes known, 5 or 6 per cent. of them are equal to from 8 to 10 per cent. of a mixture of all the fluxes usually found in clays. Hence it is better that no more than 2 or 3 per cent. of both be present in those clays in which vitrifaction is desired and in which the other fluxes occur. As a rule the shales now being used for making paving brick contain from 2½ to 3 per cent. of potash and less than 1 per cent. of soda.

From 1 to 2 per cent. of

TITANIC ACID

occurs in most shales and fire-clays, but as far as known it has no effect either as a coloring or a fusing agent. It usually occurs in the form of small brownish black grains of irregular shape, which are supposed to be a compound of iron and titanium. Like silica, its presence is not thought to be detrimental to the fire-clays in which it is found.

ORGANIC MATTER

often occurs in clays and shales, especially those of the coal measures. Usually readily combustible it is burned out at a temperature much below that of the fusing point. When in a very fine state of division it is a comparatively harmless constituent, but if in grains of any size it is apt to leave the ware more porous than it should be, especially if vitrifaction is to follow Many of the dark-colored shales which lie immediately above the seams of coal contain too much carbon to allow them to be put to any use.

CHAPTER II.

THE CLAYS OF THE COAL-BEARING COUNTIES OF INDIANA.

During the past decade an enormous expansion of the clay industries has taken place in the United States. The utilization of vitrified brick for roadways has created a new and distinct industry, thousands of miles of streets throughout the West having, since 1890, been paved with this material. The disappearance of our forests, and the consequent rapid advancement in the price of all kinds of lumber, has led architects and builders to investigate more carefully the value of clay products for structural purposes. These investigations have resulted in valuable discoveries concerning the chemical constituents and properties of clays—have suggested the invention of new, or the improvement of old forms of machinery and kilns for their manipulation and burning, and have proven their unexcelled fitness for many purposes to which stone, wood or other materials were previously put.

As a proof that the general public is beginning to appreciate this fitness, one has to but note the rapidly increasing use of terra cotta and pressed brick for the fronts of business blocks and the more fashionable and costly private residences; of clay shingles for their roofs, and of encaustic tiles for their floors and mantels. Indeed, all present signs point to clay—that most widely distributed and cheapest resource known on earth—as the leading factor in the future structures built by man.

That Indiana has not kept pace with her sister States in this rapid development and growth of clay industries is known to all who have given the matter any attention. Recent and accurate statistics compiled by the U. S. Bureau of Mineral Resources show that of the total value of clay products manufactured in the United States in 1894, Ohio made 16 per cent.; Illinois, 13 per cent.; Pennsylvania, 11 per cent.; New York, 8 per cent.; New Jersey, 6 per cent.; while Indiana made but 5 per cent, and they largely of the cruder kinds. The reason that this State ranks as low as it does lies not in the lack of quantity or variety of raw materials, nor in the lack of enterprise and capital among her citizens, but almost wholly because of the ignorance prevailing concerning the location and quality of its clay deposits and the uses to which they are capable of being put.

This ignorance is largely due to the fact that so little has heretofore been written on the clays occuring in Indiana. In 1874 kaolin was discovered in Lawrence County, and in the report of this Department for that year Prof. E. T. Cox, then State Geologist, devoted eleven pages to the description of this deposit and the iron ores connected therewith. Prof. John Collett, in the Reports for each of the years 1882 and 1883, had a part of a page on Indiana "Clays and Kaolin." In the Fifteenth Report, issued in 1885, Maurice Thompson published a seven-page paper entitled "The Clays of Indiana," and in the Sixteenth Report (1888) W. H. Thompson covered the same ground in four pages.*

With the exception of a few lines relating to local deposits of ordinary brick clays, which from time to time have appeared in the "geological surveys" of some of the counties, the above twenty-four pages comprise everything on the subject of clays that has appeared in the nineteen Reports of this Department issued to date.

This will appear the more surprising when we take into consideration the following remarkable statement made by Mr. Robert T. Hill, a noted authority on the clays of the United States: "Indiana is one of the few States that has appreciated the importance of making complete reports upon the geology of its clay deposits, and much can be learned from them in the publications of the State survey."†

Believing that the time had come when some more definite and accurate knowledge concerning the clay resources of Indiana should be made public, I began in April, 1895, to gather the data for this preliminary

* In this connection it may be stated that the late Geologist, Mr. S. S. Gorby, in his introduction to the Eighteenth Report (1893), used the following language: "The State Geologist is preparing an exhaustive report on the clays of the State, which will appear in the Nineteenth Report of this Department. In preparing for this report he has collected and made analysis of about one hundred and seventy samples of clay from all parts of the State. In this work only such clays have been used as are found in commercial quantities and at available points. Some of these clays are of extraordinary value on account of their whiteness and the large proportion of alumina they contain. It is hoped that the publication of the Report will result in a widening of the market for these valuable products."

In regard to this statement I will say that on taking charge of this office I found in the State Museum 85 jars containing samples of clays from different parts of the State. Each had a label attached containing the record of an incomplete analysis. The names of the parties owning the land from which the clays were secured were also on the labels, but in a number of instances I have found that no such persons exist in the regions from which the clays are said to have come. Not a single note, record or other manuscript pertaining to these or other clays was turned over to me, nor was anything published in the Nineteenth Report concerning them.

† "Clay Materials of the U. S." in "Mineral Resources of U. S.", 1893, p. 510. On another page the same author states that the "celebrated residual porcelain clays" of Lawrence County "are used for the making of common granite ware, hollow ware, fire and paving bricks."

report. Having no information for reference except that contained in the twenty-four pages above mentioned, and no funds to hire assistance for this especial work, I was forced to limit the investigation of the season to such an area as I could visit personally during such time as could be spared from the routine work of the office. I chose, therefore, the coal bearing counties—eighteen in number—for the principle reason that the coal measures of the State are preëminently its clay measures—a coal seam wherever found having associated with it a bed of fire clay and usually one or more of shale; two forms of clay material which within the past ten years have become so noted for the making of vitrified wares.

The counties comprising the area covered by this report are, therefore, as follows: Fountain, Vermillion, Parke, Vigo, Clay, Owen, Sullivan, Greene, Knox, Daviess, Martin, Dubois, Pike, Gibson, Vanderburgh, Warrick, Spencer and Perry. Posey County, lying in the extreme southwestern corner of the State, has its surface wholly covered with the rocks of the upper or barren coal measures. Little, if any, coal is mined in the county and, therefore, a report on its clays is deferred until a future time. The limited time at my command forbade anything like a thorough study of *all* the clay deposits in these counties; and, therefore, detailed mention is made only of those which are notable for the quantity and quality of the material found in them.

Before taking up these counties singly let us briefly notice as a whole the area which they comprise and gain some farther facts concerning the origin and deposition of the shales and fire clays found therein.

The surface of the counties mentioned comprises the newest part of Indiana, *i. e.*, it was the last to be raised above the surface of the water and become dry land. The outcropping or underlying rocks of the remainder of the State were all deposited in salt water, probably at great depths, and were raised upward and became dry land thousands of years before the coal and its overlying shales were formed. They are, therefore, for the most part *limestones*, and the many fossils which they contain are mostly of marine animals. The rocks of the coal measures were mainly deposited in fresh water and are for the most part *sandstones and clays*. These contain few fossils and they are largely the remains of such plants as formed the coal.

It is most probable that at the time of the formation of the coal and its overlying shales and sandstones the area comprised in the counties mentioned, as well as a part of eastern Illinois, was a great basin or depression but little above the level of the sea, and surrounded on every side except the southwestern by the higher lands of the older formations.

By successive alternations of upheaval and subsidence—carried on through thousands of years—this depression was at times an area of the southwestern sea, again a fresh water lake, and then for a period, a vast swamp or marsh. When raised high enough to form a marsh a luxuriant vegetation sprang up from the ooze and mud at its bottom, flourished for centuries—the newer growths springing from between the fallen masses of the older as in the peat bogs of to-day—and so formed a mighty mass of carbonaceous material.

By subsidence the level of the marsh was, in time, lowered until it became a lake into which rivers from the surrounding highlands flowed, bearing with them millions of tons of clayey sediment and disintegrated quartz, the remains of the older decayed rocks. This sediment was spread out over the mass of submerged vegetation, compressing it into the hard, mineral coal; the clayey sediment itself being in time compressed into vast beds of *shale*, and the particles of quartz into sandstone. In some places a more prolonged subsidence took place, sinking the floor of the lake below the level of the sea, and allowing the waters of the latter with their accompanying marine forms of life to flow in. In time beds of limestone were then formed over those of the shale or sandstone, but none of these cover an extensive area or are of great thickness.

After each subsidence, with its resulting beds of coal, shale and sandstone or limestone, had taken place an upheaval followed. The floor of sea or lake was again raised so near the surface that the semi-aquatic vegetation for a new coal seam could spring up, and, in time, the processes detailed above were again undergone. Thus, in brief, do scientists account for the origin and formation of those seams of coal which are to-day the chief mineral wealth of our State, and of those beds of overlying shale, as yet, almost wholly undeveloped, but in time destined to become as great a source of wealth as the coal has been in the past or will be in the future.

A typical vertical section showing the arrangement of the different coal measure strata as mentioned above, and their relation to each other, would be as follows:

(1)	Soil and surface drift clay	9 feet.
(2)	Blue, compact shale	27 feet.
(3)	Dark bituminous shale	3 feet 2 in.
(4)	Coal	2 feet 7 in.
(5)	Fire clay	4 feet 4 in.
(6)	Drab silicious shale	18 feet.
(7)	Sandstone	6 feet 3 in.
(8)	Dark bituminous shale	1 foot.
(9)	Coal	4 feet 8 in.
(10)	Fire clay	3 feet 10 in.

Some of these strata are closely related. The fire clays (Nos. 5 and 10) are almost universal accompaniments of the overlying coal seams. The relation of these under-clays to the coal show plainly that the former may be regarded as having formed the soils of those ancient marshes, and that from them sprang that luxuriant vegetation which in time was changed to coal. The fire clays, then, are the mother soils of the coal seams. They are usually from one to six feet in thickness, and composed of a soft, homogeneous clay, whitish or gray in color, highly plastic, and, when sufficiently free from the fluxing elements, capable of withstanding in a remarkable degree the action of heat. It is important to remember that these under-clays of the coal seams are the only sedimentary clays which possess in a high degree this refractory property. Its presence in them is due to the absence of a large percentage of the alkalies and other fluxes. This absence is the more notable since all other sedimentary clays contain these fluxes in quantities sufficient to cause fusion at a comparatively low temperature. Their disappearance from the fire clays is explained by the fact that these clays formerly supported so vigorous a growth of aquatic plants; for it is a well proven fact that such vegetation, aided by organic acids which are formed in the submerged soil, has the power of absorbing from such soil all or nearly all the alkalies, iron and sulphur found therein. This leaves the soil rich in silica and alumina, which are the leading constituents of the fire clays. The absorption of the iron oxides also causes these clays to assume that ashen gray color so characteristic of them.

Few, if any, fossils are found in these under-clays. The only things approaching them are the remains of the many long, thread-like roots, or underground stems (Stigmaria) of the larger plants (*Sigillarids* and *Lepidodendrids*) of the former coal flora.

The dark bituminous shales (Nos. 3 and 8 of the above typical section) are found lying directly upon most seams of coal, and constitute the so-called "black slate" of the miners. They vary much in thickness, and are usually very complex in their composition—being nothing more than the first mass of mud, impregnated with carbonaceous matter, which was deposited on the submerged vegetable remains in the old coal swamp. This mud was compressed and hardened into its present condition by the great mass of material afterwards deposited upon it. Oftentimes these shales are very fissile, and cleave in large, flat leaves as thin as paper. Again they are massive, with no visible signs of stratification. The amount of bituminous matter which they contain is usually too great to allow them o be put to use as a clay material. Many of them contain a large percentage of oily matter, which, if necessity should arise, could probably be distilled in paying quantities.

These overlying dark shales comprise the most noted fossil bearing horizon of the coal measures. They contain by far the greater number of those handsome impressions of the leaves of ferns and closely allied plants which are so characteristic a part of the fossil coal flora. The remains of mollusks are, in some localities, also abundant in these shales—the lamellibranchs and gasteropods being the chief groups which are represented.

The blue and drab shales (Nos. 2 and 6 of the section) comprise the greater part of the coal measure rocks* of Indiana, and, taken as a whole, are the most valuable clay deposits occurring in the State. They are not closely related to the strata found above or below them, and their thickness and composition varies excessively and is dependent entirely upon the character and source of those streams of water which flowed into the old lakes in which the shales were formed. If the stream was a large one and flowed for a long time with sufficient velocity to carry sediment far out into the deeper part of the lake, the bed of shale is thick, covers a large area, and is comparatively uniform throughout. On the other hand, if the stream was small and flowed slowly the shale bed is correspondingly thin, of small extent, and more apt to be varied in its composition. The kinds of rocks over which those ancient rivers flowed on their way to the lake determined the constituents of the sediment they brought down, and therefore the character and composition of the shales into which this sediment was afterward formed.

In general the shales may be classified into

(1) Argillaceous Shales,

in which clayey material (silicate of alumina) largely predominates. In color these are usually drab or blue, though yellow and buff shades are not of uncommon occurrence. They are almost free from "grit" and are often soft and unctuous or greasy to the touch. They are then known locally as "soapstones," but this term rightfully belongs to the mineral steatite or talc, a magnesian silicate which does not occur in Indiana. Sometimes, however, the shales are quite hard and tough, yielding but little to the pick and requiring the use of explosives for their removal. But whatever their character when first mined, upon exposure to air, rain and frost, they quickly disintegrate into soft, plastic, fine grained clays of large commercial importance.

(2) Arenaceous or Silicious Shales

are those which have a large proportion of free silica or sand mixed with the clayey material. For the most part they are drab, buff or yellow in color, though sometimes gray or even bluish. Their value for manufacturing purposes depends largely upon the character of the sand particles found in them. Sometimes these particles are so minute as to be invisible to the naked eye. The shales are then comparatively free from "grit," and are scarcely inferior to the argillaceous shales in value.

*The term "rocks," in this report, is used in its true sense, and signifies any material whether hard or soft which constitutes a portion of the crust of the earth. Thus, a bed of sand or clay is no less a rock than the hardest granite.

Again, the grains of sand are larger and plainly discernible to the sense of touch as well as sight. When of this character the deposits are rightfully known as shaly sandstones and are of little economic importance. Oftentimes scales of mica are scattered abundantly among the particles of sand, and the shales are then known as "micaceous."

Much less common in the coal area than either of the preceding are the

(3) Calcareous Shales.

These contain a large percentage of carbonate of lime ($CaCO_3$) commingled with the clayey material. Such shales may be readily known by their light grayish color and the readiness with which they effervesce with muriatic acid. Where found they are usually in close connection (either above or below) with a stratum of limestone. Oftentimes they contain remains of the shells of marine or brackish waters. Surrounded as they are by so much material of better quality these calcareous shales of the coal measures are of little commercial importance. In some of the older formations (Silurian, Devonian, etc.), where good clays are less common, they may be utilized in making bricks when the percentage of lime is not too great and is disseminated evenly throughout the shale.

At times sharp lines of division separate the varieties of shales; but generally they merge so gradually into one another that it is often difficult to say where the one ends and the other begins. Thus, by the gradual addition of fine particles of sand the argillaceous shales pass into arenaceous; these, by the addition of coarser particles, into shaly sandstones, and finally into hard and durable sand rocks.

Specimens of almost all of the deposits of clay mentioned on the following pages, as well as many samples of their burned products, are in the collection belonging to the State, and all persons interested in clays or clay manufacturing are cordially invited to call at the office of the State Geologist and examine them.

I desire at this place to express my indebtedness to the many persons residing in the counties visited, who aided me in my researches. The number is too great to allow of individual mention. Everywhere I was treated most courteously and afforded every facility for securing the knowledge which I sought. I shall long remember the favors shown me and hold myself in readiness to reciprocate whenever opportunity offers.

PARKE COUNTY.

The rocks of the Coal Measures proper cover three-fourths of the area of Parke County. The conglomerate sandstone (millstone grit), marking their eastern horizon, extends from a point near the center of the northern boundary in a southeasterly direction and touches the southeastern corner of the county. The most important clay deposits are found west of this sandstone in the northwestern, western and southern townships. The Wabash River forms the western boundary of the county and receives many important tributaries from the eastward. These and their smaller branches have, in numerous places, eroded deep beds through the surface strata exposing the latter to view and affording excellent opportunities for discovering the thickness and character of the coal measure rocks.

Parke County has long been famous for its potters clays. Since the year 1840 a clay for the making of stoneware has been obtained from land now owned by Pearly Pearson and Milton Hobson (N. W. ¼, Sec. 23, Tp. 16 N., R. 8 W.) one mile southwest of Bloomingdale. A branch of Leatherwood Creek flows through this land and at several points along its low bluffs the clay is obtained by stripping. At the time of my visit the following section was obtained at the latest pit worked on the Pearson land:

1. Soil and drift clay	3 ft.	
2. Gravel	3 ft.	4 in.
3. Coarse, silicious fire clay	3 ft.	3 in.
4. "Iron sandstone"	1 ft.	10 in.
5. Fine grained potter's clay (exposed)	8 ft.	

This potters clay (No. 5) is of a grayish or lead color, quite soft and plastic, and much more so when washed and kneaded. It contains a large amount of free silica in very fine grains and, at scattered intervals, scales of white mica are discernible. It burns to a buff or cream color, and takes a handsome dark glaze with Albany slip clay.

A sample analyzed by Dr. J. N. Hurty* showed the following percentage composition:

* All analyses credited in this report to either Dr. J. N. Hurty or J. D. Kramer are incomplete, showing the presence of neither potash nor soda. I have taken these analyses, when given, from the labels on the jars of clays mentioned in the foot note on page 41. They were made for S. S. Gorby, the former Geologist. Dr. Hurty is a reliable chemist of Indianapolis, and his analyses are doubtless correct as far as completed. Of Mr. Kramer's ability as a chemist I know nothing. Prof. W. A. Noyes, the official chemist of this Department, has made especially for this report all the analyses with which he is accredited. He is a chemist of national renown and his analyses can be relied upon in every particular. Prof. Lyons, of the State University, completed eight analyses after the burning of Prof. Noyes' laboratory in November, 1895.

Silica (total)	69.41	
Alumina	18.81	
Clay-base and sand		88.22
Magnesia	.54	
Lime	.90	
Ferric Oxide	2.64	
Fluxes		4.08
Water and volatile matter	7.65	

Compare with the second column of this the average composition of ten leading stoneware clays of Ohio: *

Clay-base and sand	94.10
Fluxes	4.44
Moisture	1.57

It is probable that some of the matter classed as volatile in the Indiana specimen comprises the undetermined potash of which from 1 to 2½ per cent. is always present in these clays. Nevertheless, the percentage of refractory material present shows that it will stand up under heat sufficient to melt the "slip-clay" used for glazing—a fact which experience has fully verified.

This stratum of potter's clay covers a large area south and west of Bloomingdale. Its maximum thickness is not known, but Mr. Hobson reported that at a point one-quarter of a mile east of where the above section was obtained, thirty feet of it was passed through in digging a well. No charge has ever been made for it by the owners of the land; but for more than fifty years it has been washed by potters near the place where mined, and then hauled in wagons six miles to Rockville. It has also been used for five years in the pottery at Bloomingdale, and to a small extent in the one at Annapolis. Many pits have been opened along the bluffs of Leatherwood, worked back a short distance, and abandoned as soon as the stripping became in anyways heavy. In almost all of these the clay was very uniform in character and quality, though in a few, the presence of small nodules of iron carbonate detracted from its value.

The coarse silicious clay (No. 3 of above section) is used at Bloomingdale in making a cream colored drain tile. Mixed with surface clay it is also burned into a good quality of building brick. In some places, however, it contains too many pebbles of limestone from the overlying gravel to be of any value. The "iron sandstone" (No. 4) separating the two clays is a very heavy and hard, dark colored, coarse grained rock, evidently a combination of some ore of iron and sand.

One-half mile west of the pit where the above section was taken a stratum of clay outcrops a few feet above the bed of Leatherwood Creek.

*Orton, Edw., Jr.—Geol. Surv., Ohio, VII., 95.

Although possessing at this place the physical appearance of a gray silicious shale, its behavior under heat proves that it is a fire clay, as it has undoubted refractory properties and burns to a handsome buff color. Its composition, as far as determined by Kramer, is as follows:

Silica (total)	73.32
Alumina	16.06
Magnesia	.70
Lime	.70
Ferric oxide	1.10
Moisture and volatile	8.12

It is hard when first mined but soon weathers into a soft plastic mass. The thickness of the stratum has not been determined. Its known properties are such as to merit further investigation.

Three miles northwest of Bloomingdale, on the land of R. A. Coffin (N. E. ¼, Sec. 9, T. 16 N., R. 8 W.), is the head of "Coke Oven Hollow," a deep ravine, long locally noted for the quantity and variety of the clays found therein. A pottery was established in this ravine in 1866 and continued in operation until 1891. It was located on ground made vacant by the mining of fire and potters clay for shipment over the old Wabash & Erie Canal, which was connected by a feeder with the mouth of the ravine, and for use in the pottery at Annapolis.

A connected section of the strata in the upper half of this ravine is as follows:

1.	Soil and yellow drift clay	8 feet.
2.	Buff argillaceous shale	27 feet.
3.	Hard, gray silicious shale	4 feet 6 in.
4.	Coal	1 foot 3 in.
5.	Fire clay	3 feet 4 in.
6.	Blue argillaceous shale	8 feet 8 in.
7.	"Iron sandstone"	1 foot 6 in.
8.	Plastic potters clay	22 feet.
9.	Dark, hard arenaceous shale merging into sand rock	21 feet.
10.	Coal	2 feet. 8 in.
11.	Fire clay	3 feet 10 in.

The potters clay (No. 8) is, doubtless, the same stratum as the one worked at Bloomingdale; the overlying "iron sandstone" of the two being identical in appearance. In its crude form the potters clay at "Coke Oven Hollow" contains more or less impurities, but when carefully washed and mixed with about one-eighth its bulk of fire clay, it burns into that strong, gray, vitrified stoneware which, since 1841, has been made at the Annapolis pottery.

The two shales (Nos. 2 and 6 of the above section) are valuable deposits; suitable in the highest degree for paving brick, sewer pipe or other vitrified products. The fire clays (Nos. 5 and 11) are also excellent in quality. Sample brick, made from the lower clay (No. 11) have been tested a number of times and have held their own in refractory properties with the best fire brick in the market. Large quantities of this clay were formerly shipped by the canal to Toledo, Ohio, and points in northern Indiana. The arenaceous shale (No. 9) contains too large a percentage of silica and mica, in coarse particles, to be of value.

The outcrops of the lower vein of coal (No. 10) have been mined for many years. It is a bituminous coal of good quality, and, locally, much valued for smithing purposes. Taken by itself the vein is too thin for profitable working. Mined in connection with the overlying clays as fuel for their burning, a profitable industry could be started here were it not for the lack of transportation facilities. Until these are secured the valuable mineral deposits of "Coke Oven Hollow" must remain practically undeveloped.

The bluffs of Sugar Creek and its tributaries, in the northern tier of townships, contain large and numerous deposits of shales suitable for manufacturing purposes. The largest and most accessible of these are found on both sides of Sugar Creek in sections 25 and 26, Tp. 17 N., R. 7. W. For nearly two miles above the "Narrows" high shale bluffs are numerous, the exposures reaching a thickness of 75 or 80 feet. It is, for the most part, a black fissile, argillaceous shale, containing more or less iron pyrites and clay ironstones and interstratified with thin seams of coal and fire clay. In places along this bluff there is considerable sandstone in the shale, in other places there is very little.

Heavy beds of shale are also found along Sugar Mill Creek in sections 4, 10, 21, 28 and 29, Tp. 17 N., R. 7 W. The largest of these and the one in the best position for working is at "the Pinnacle," on the west side of the Creek (S. E. ¼ Sec. 21, Tp. 17 N., R. 7 W.). At this point the Creek cuts off the end of a narrow ridge 50 feet high having a narrow ledge of sandstone, 10 feet thick, on top; the lower 40 feet consisting of drab to black colored shale. The shale lies in a heavy bed in the northern part of Section 28 on the south side of the Creek, where it contains a bed of coal nearly three feet thick.

On a small tributary of Sugar Creek from the south in Sec. 8, Tp. 17 N., R. 6 W., is an outcrop of blue shale resembling that so extensively used at Veedersburg, Indiana, for making vitrified brick. This deposit varies from 20 to 40 feet in thickness along the bluff.

In the vicinity of Montezuma, Parke County, and Hillsdale, Vermillion County, are found some of the largest deposits of shale and fire clay occurring in the State of Indiana. The Wabash River, flowing north and south between the towns mentioned, forms the boundary line separating the two counties. Montezuma is situated on the eastern bank of the river, on the edge of a river terrace. This level terrace or river plain extends eastward one and one-half miles and there meets the bluff or upland which marks the eastern bank of the old river channel. On the western side of the river a stretch of level land, overflowed during high waters, extends for three-fourths of a mile to a very narrow terrace, on which the town of Hillsdale is partly located, and from the western side of which the bluffs, marking the western bank of the old river, rise abruptly.

The deposits of shale and fire clay above mentioned are found in the bluffs on both sides of the Wabash River. The I., D. & W. Railway runs east and west through Montezuma and Hillsdale. One-eighth of a mile west of where it strikes the bluff in Parke County it is crossed by the I. & I. C. Railway running north and south. A large tract of land located in the southeastern angle of their intersection has been recently purchased by the Marion Brick Company of Marion, Indiana. A connected section obtained on the sides of the bluff and in a well at its base, on this land, and on that of Thos. Morgan (S. W. ¼ Sec. 31, Tp. 16 N., R. 8 W.) adjoining it on the south, discloses the following strata:

1.	Surface soil and gravel	8 feet.
2.	Drab argillaceous shale	12 feet.
3.	Clay ironstone	3 in.
4.	Dark bituminous shale	5 feet 4 in.
5.	Coal	1 foot 2 in.
6.	Fire clay	6 feet.
7.	Bluish gray argillaceous shale	35 feet.
8.	Blue argillaceous shale	9 feet.
9.	Dark bituminous shale	1 foot 4 in.
10.	Coal	1 foot 8 in.
11.	Fire clay	3 feet.

From the above it will be seen that not less than 65 vertical feet of workable material are comprised in the three shales (Nos. 2, 7 and 8) and the two fire clays (Nos. 6 and 11) at the points mentioned.

The bluish gray shale (No. 7) is so soft as to be easily scratched by the nail, exceedingly fine grained, and has a very smooth and unctuous feel. Where exposed vertically by erosion, it weathers at first into small quadrangular blocks a few inches in surface dimensions. These in time break up into finer particles, which are washed down and give a characteristic grayish yellow tinge to the surface of the bluff for miles in either direction. Numerous tests of this shale have been made by the Marion Brick Company, and by the Wabash Roofing Tile Company, of Montezuma. When burned to near the point of vitrifaction it becomes a bright cherry red. When vitrified it is a dark brown, but if heated beyond this point it quickly becomes black, porous and worthless. It is especially suitable for making dry pressed brick for the fronts of buildings. It also makes an excellent roofing tile, as the very thin sheets of clay, when properly prepared for the kiln, do not shrink or warp to any appreciable extent while burning. It is, therefore, the sole material used in the manufacture of roofing tile by the company at Montezuma.

This bed of shale merges gradually into the stratum of blue argillaceous shale (No. 8) at its base. The latter is a somewhat harder and tougher material and burns to a darker red. By itself, or mixed with equal parts of the overlying gray shale, it will make a most excellent vitrified brick. Occasional nodules of kidney iron ore are found in the lower part of this stratum.

The upper fire clay (No. 6), where exposed on the Morgan land, is an almost white, highly silicious deposit, remarkably free from oxides of iron and other impurities. Large quantities of it have been burned into fire bricks and saggers by the Roofing Tile Company at Montezuma. The brick were finer in texture and more compact than those made from the fire clay at Hillsdale and Highland across the river. As far as used their refractoriness has proven to be of the highest.

The bluff for two miles north and nearly the same distance south of the railroad junction is largely composed of the above mentioned shales and fire clays. On the lands of O. P. Brown (Sections 30 and 19), one-half mile east of the I. & I. C. R. R., the shales are especially notable, at one point (N. W. ¼, Sec. 30, Tp. 16 N., R. 8 W.) the exposure of the gray and blue varieties together measuring 51 feet in vertical thickness.

By the side of the Rockville and Montezuma road, on the land of Benj. Phillips, valuable deposits of similar materials also occur. A bed of buff shale 25 feet thick overlies a thin seam of coal. Beneath this is a vein of fire clay 6 feet in thickness, and lower down a deposit 12 feet thick, of superior argillaceous shale of the kind locally known as "soapstone." Both this and the upper shale are very free from impurities and weather into a very fine-grained, plastic clay. The point where they are found is one and one-half miles from the I., D. & W., and one mile from the I. & I. C. R. R.

On the east side of Troutman's Branch, west of the Hollandsburg-Mansfield road, near the middle of Section 16, Tp. 15 N., R. 6 W., is a nearly perpendicular bluff of blue-drab shale 40 feet or more in thickness, with little covering. The upper part of the bed has a dull yellow to buff color, the lower part a blue-drab. The shale is nearly uniform in texture throughout the bed, except a stretch 3 or 4 inches thick near the middle, which is a fine-grained sandstone.

A section of the bluff shows:

1. Glacial drift and soil .... 2 to 3 feet.
2. Blue-drab shale, weathered buff on the surface and containing a layer of sandstone 3 to 4 inches, exposed .... 35 feet.

The shale extends below the level of the creek, and the total thickness is unknown. Other exposures of shale occur along Troutman's Branch, but none were observed so large or so favorably situated for development as the one described above.

A more compact form of blue shale has been quarried to some extent in Section 5, Tp. 15 N., R. 6 W., for use in fire-places, because of its fire-proof qualities.

Along the bluffs of Big Raccoon Creek in Wabash Township are some of the leading clay deposits of Parke County. The most valuable of these, as far as variety, quality and accessibility of the clays are concerned, are found at Mecca, on the lands of S. L. McCune (S. E. ¼ Sec. 20 and S. E. ¼ of N. W. ¼ Sec. 20, Tp. 15 N , R. 8 W.), where the following strata are exposed in a connected section beginning near Shaft No. 2 of the Otter Creek Coal Co., and extending down the ravines in a northwesterly direction to the mouth of "Oklahoma Hollow:"

1.	Soil and drift, "hard pan,"	5 to 18 ft.
2.	Light blue arenaceous shale	20 to 35 ft.
3.	Coal—double vein with thin fire clay parting	2 ft.
4.	Fire clay—light gray	4 ft. 8 in.
5.	Drab to buff argillaceous shale	28 to 36 ft.
6.	Dark, fissile bituminous shale	1 ft.
7.	Coal	1 ft. 8 in.
8.	Fire clay—bluish gray	5 ft. 4 in.
9.	Soft, dark blue argillaceous shale	8 ft.
10.	Dark, fossiliferous limestone	4 to 10 in.
11.	Black fissile shale with large nodules of kidney iron ore	2 ft. 6 in.
12.	Coal	1 ft. 2 in.
13.	Fire clay—dark colored	1 ft. 8 in.
14.	Light gray argillaceous shale	8 to 10 ft.
15.	Dark bituminous shale with streak of coal at base	4 ft.
16.	Fire clay—light bluish gray	5 ft. 2 in.
17.	Hard, dark silicious ironstone	2 ft.
18.	Dark gray silicious shale	12 ft.
19.	Bituminous shale	4 ft.
20.	Coal	2 ft. 8 in.
21.	Fire clay—light gray and coarse grained	4 ft. 6 in.

Outcrops of all the above strata are visible along the sides of the ravines, except the last two, which are found in the bottom of the large ravine known as "Oklahoma Hollow." Of the shales and fire clays, Nos. 2, 4, 5, 8, 9, 13, 14, 16, 18 and 21, aggregating not less than 97 feet and in places 122 feet in vertical thickness, occur in the area mentioned. Of these the following are so valuable as to be worthy of more extended mention.

The light blue shale (No. 2) is located by the side of the switch running to No. 2 coal shaft and can be easily stripped and loaded directly into cars. It contains a large amount of free silica in fine grained particles. Three thin bands of kidney iron ore are found in the lower half of this stratum at intervals of two feet apart. A sample of this shale analyzed by Prof. Noyes, shows that it contains of

Clay-base and sand	85.70 per cent.
Fluxes	12.49 per cent.

According to Orton, loc. cit., p. 134, the average composition of the shales used by ten of the leading paving brick and sewer pipe factories of Ohio is

Clay-base and sand	84.78 per cent.
Fluxes	13.22 per cent.

with a variation in the ten of only 4.1 per cent. in clay and sand and 6.04 per cent. in fluxing ingredients. Taking this *as a future standard of comparison for the composition of Indiana shales suitable for vitrified products*, we find that the one under consideration ranks high and may be classed as well fitted for the making of paving brick.

The bed of drab and buff argillaceous shale (No. 5) is a most valuable deposit. It is so situated that millions of tons can be loaded directly onto the switch running to coal shaft No. 1 or onto a short spur, easily constructed. Sixty car loads of it have been shipped to Chicago Heights and used by the Ludowici Tile Company for making roofing tile. Samples have also been burned into red pressed front brick that can scarcely be equalled in quality or appearance. According to analyses made by Prof. Noyes, it contains of

Clay base and sand	87.09 per cent.,
Fluxes	13.43 per cent.,

showing that it ranks almost as close as shale No. 2 to the standard composition of material suitable for vitrified products.

Quantities of the bluish-gray under-clay (No. 8) have been shipped to the Northwestern Terra Cotta Works of Chicago and used as the body clay in the making of structural terra cotta. The upper part of the vein burns to a bright buff and the lower to a darker, almost tan color. Handsome pressed front brick of the latter tint, made from this deposit, are now in the State collection of Indiana clay products.

The analysis of a specimen of this clay shows the presence of

Clay base and sand	89.87 per cent.*
Fluxes	10.50 per cent.

The large percentage of fluxes in this underclay shows that it is not a "fire clay," properly speaking, and any attempt to make refractory

*For complete analyses of these clays see the table at the end of this chapter.

products from it would doubtless result in failure. It can be made into sewer pipe of good quality, but the use to which it is best adapted is probably that for which it has already proven its superiority—the making of terra cotta and buff front brick.

The stratum of dark argillaceous shale (No. 9) has been practically tested in the making of paving brick, 75 or more car-loads having been shipped to the Indiana Paving Brick Company of Brazil, and used for that purpose. The bricks from it were as tough and durable as any from the noted stratum of Brazil shale to be described hereafter. No. 9 shale is softer and smoother to the sense of touch than any of those overlying it in the section given. Near the bottom of this stratum are numerous nodules of kidney iron ore which can be readily thrown aside by the miner. A sample of the shale was analyzed by Prof. Noyes and found to contain:

Clay base and sand	88.64 per cent.,
Fluxes	11.51 per cent.,

showing that it falls within the limit of variation from the standard composition which a good vitrifying material may take.

Fire-clay (No. 16), outcropping beneath the switch leading to coal shaft No. 1, is another valuable deposit. It is very soft and plastic where exposed, and so light colored that it is often used by the miners for whitewashing. It burns to a handsome light buff, and a number of high grade front brick have been made from it for Mr. McCune by the Cayuga Pressed Brick Company. It contains, according to analysis:

Clay base and sand	94 12 per cent.,
Fluxes	6.35 per cent.,

showing that it is a purer and much more refractory under-clay than the one above mentioned. Its composition is very close to that of the famous stoneware clays found about Akron, Ohio.

Neither tests nor analyses have been made of the upper fire-clay (No. 4) or the lower (No. 21) of the above section; but, judging from appearances, both are typical fire-clays of high refractory properties. The lower is almost white, and in texture and general appearance resembles more closely that at Highland, from which the well-known Montezuma fire-brick are made, than does any similar deposit so far known to occur in Indiana.

The Otter Creek Coal Company mines, from the same land on which the above clays are found, a semi-block coal. It is taken from a lower vein than any given in the above section. As a fuel either for domestic or manufacturing purposes it takes a rank among Indiana coals second only to "Brazil block." At Veedersburg and Montezuma, where it has long been used in the making of paving and fire brick, it is pronounced the best fuel which can be secured for burning these products. Running to each of the coal shafts, and passing by the side of the main strata of shales and fire clays, are switches of the I. & I. C. Railroad. Raccoon Creek, with a never-failing supply of water, is within one-eighth of a mile of the leading deposits. With an unlimited supply, in great variety, of the better grades of shales and fire clays, with good transportation facilities already constructed, and with excellent fuel and plenty of water —all in one place—this is the most eligible location for a great clay industry which Parke County possesses. Indeed, few better can be found in the State.

On the western bluffs of Big Raccoon Creek similar deposits occur, but are not so extensive. The Dee Sewer Pipe Company, of Chicago, has purchased land and, during the past summer, erected a large plant on the northwestern quarter of Sec. 19, Tp. 15. N., R. 8 W., where they will soon begin the manufacture of sewer pipe and kindred products on an extensive scale. Two strata each of shale and fire clay, aggregating 45 to 50 feet in thickness, were exposed at the time of my visit. The shales had been tested and found to make a pipe of good quality. One-half mile south of the Dee factory, on the land of Solomon Dixon, the same beds of shale are exposed just west of the I. & I. C. Railway. A more extended investigation will doubtless disclose their presence over a large area of the higher land between Mecca and the Wabash River.

Four and one-half miles west of Rockville, along the stream known as Rocky Run, in the N. W. ¼, Sec. 3, and the N. E. ¼, Sec. 4, Tp. 15 N., R. 8 W., occurs a large deposit of exceedingly fine-grained sandy clay known as "slip-clay." This is a natural glaze, of a highly fusible quality, which when melted over the surface of stoneware gives to it a brilliant color and finish. The essential property of a "slip-clay" is low fusibility, for it must melt at a lower temperature than the clay used in the body of the ware, else the latter will not stand up under the heat required to melt the glaze. The best slip-clay in use among potters comes from Albany, N. Y., and costs in small lots about $2.10 per barrel. To the ware made from the potters clay found at Bloomingdale and Coke Oven Hollow this gives a brilliant, smooth, dark brown surface. The slip-clay from Rocky Run is used by the potters of western Indiana to glaze the inside of the ware. It gives a reddish-brown glaze, somewhat rougher than that produced by the Albany slip.

The Rocky Run slip-clay was analyzed by Dr. Levette and the analysis published in the Report of the Geological Survey of Indiana, 1878, p. 159, as follows:

Silica (total)	55.20	
Alumina	14.40	
Clay base and sand		69.60
Ferric oxide	9.40	
Manganic oxide	1.80	
Lime	6.12	
Magnesia	.90	
Soda	.52	
Sulphuric anhydride	.34	
Fluxes		19.08
Moisture and volatile		8.60

Comparing with the last column of these figures the following average composition of six slip-clays used in the leading potteries of Ohio—

Clay base and sand	69
Fluxes	21
Moisture and volatile	9

we see that the Rocky Run clay possesses the necessary constituents of a successful natural glaze. As such it should be more thoroughly investigated by Indiana potters.

Numerous other large deposits of shale and fire clay occur in the eastern and southern parts of Parke County, but only brief mention can here be made of a few of them, as follows:

West of Hollandsburg, along a small tributary of Raccoon Creek (Sec. 9, Tp. 15 N., R. 6 W.), is a conspicuous bluff in which 26 feet of yellow and drab argillaceous shale is exposed, and can be easily secured by stripping. On the hill north of Ferndale (Sec. 27, Tp. 15 N., R. 6 W.) is a bed of drab argillaceous shale more than 30 feet thick, overlain by a heavy bed of drift. Both of the above deposits are suitable for vitrified products.

Beds of "fire-clay," suitable for terra cotta or sewer pipe, are exposed in the N. W. ¼ Sec. 4, and in the N. W. ¼ and S. E. ¼ Sec. 14, Tp. 14 N., R. 6 W.

In the vicinity of Caseyville, near the Clay County line, thick deposits of both shale and fire clay have been exposed in mining the block coal. Switches from three railroads penetrate this region and give abundant facilities for shipping, At the "New Superior" mine (S. W. ¼, Sec. 35, Tp. 14 N., R. 7 W.), operated by the Superior Block Coal Company, of Brazil, the top vein of coal is overlain with 11 feet of dark blue argillaceous shale, and underlain with 4½ feet of a superior quality of dark, plastic "fire clay." At the time of my visit much of this under-clay was being loaded for shipment to Chicago, there to be made into terra cotta. It brought 45 cents a ton at the mine. As some of it had to be taken up to make height in the rooms and entries, a fair profit was realized at this price. Thousands of tons of it, mixed with other useless materials, were going to waste on the dump. The same stratum underlies a large area in northern Clay and southern Parke counties.

From what has been said it may be seen that Parke County abounds in clays suitable for ordinary and pressed front brick, terra cotta, roofing tile, sewer and drain pipe, paving brick, stoneware and refractory products. Only the larger and more notable deposits have been mentioned in the foregoing pages. Many others of as good quality doubtless occur. These rich resources are as yet practically undeveloped. Aside from a few small stoneware potteries and brick yards, supplying a local trade, there are but two factories for making clay products located in the county, the Dee Sewer Pipe Company, of Mecca, and the Wabash Roofing Tile Company, at Montezuma. These have been started within the past two years. They are but the forerunners of others to come, for the raw material is there, the fuel in abundance to burn it is there, four railroads pass entirely through the county and two others touch its borders, all ready to carry the completed products to the four corners of the globe. With these facilities present, capital in time will come, will be invested, and will make the county a great clay industrial centre.

FOUNTAIN COUNTY.

Two reports have hitherto been written upon the geology of Fountain County. One, by Prof. E. T. Cox, was published in 1869; the other, by Dr. R. T. Brown, in 1881. The investigations which these parties made were primarily in search of coal, and, therefore, the deposits of clay, which in time will prove of far greater value than the coal in the county, were scarcely touched upon.

The entire surface of Fountain, as of Parke County, is covered with a deposit of glacial drift—soil, gravel, sand and clay—in some places attaining a thickness of more than 100 feet On this account it is only where coal shafts or bores have been put down, or where streams have eroded ravines and gulches, that the character and value of the underlying strata can be ascertained.

The central and western townships of the county are well drained by Shawnee and Coal creeks and their numerous tributaries, as well as by a number of smaller streams which flow directly into the Wabash River. It is, therefore, in these townships that the thick deposits of shales, which underlie the greater part of the surface of the county, can be most readily obtained. The coal area is, for the most part, included in the southwestern fourth of the county, and there, of necessity, the valuable underclays are located.

Beginning in the north we find on the "Hegler farm" (W. ½ of S. W. ¼, Sec. 34, Tp. 22 N., R. 7 W.), one and one-half miles northeast of Attica, an outcrop of a bluish-gray arenaceous shale, 22 feet of which is exposed. It is found in a ravine less than one-fourth of a mile east of the main line of the Wabash Railway. The shale is overlain with from 3 to 6 feet of soil and yellow clay, and at intervals throughout the exposure are thin seams of sandstone 2 inches to 1 foot thick, there being 3 such layers in the 22 feet exposed. The shale weathers into a fine grained, very plastic clay, suitable for pressed front brick or vitrified products.

Farther northeast, at the point in Secs. 19 and 20, Tp. 22 N., R. 6 W., at which the wagon road crosses the stream known as "Turkey Run," is a bed of similar shale 30 feet thick. This is but one-third of a mile south of the Wabash Railway, and like the preceding may be gotten by easy stripping.

About two miles west of Rob Roy in the S. E. ¼, Sec. 23. Tp. 21 N., R. 8 W., Shawnee Creek has eroded a bed through a thick stratum of blue argillaceous shale. Thirty-two feet are exposed at the point mentioned, which is about one mile east of where the Attica & Covington Railroad crosses the stream. This deposit is less silicious than the ones above noted, and on that account is capable of being made into a greater variety of products. The same stratum outcrops at other points along Shawnee Creek, but this is the largest exposure which was seen.

On Rattlesnake tributary to Bear Creek (S. E. ¼, Sec. 4, Tp. 20 N., R. 8 W.) Mr. Geo. Galloway some years ago sunk a shaft in search of clays, a section of which shows as follows:

1.	Soil	3 feet.
2.	Black sandstone	4 feet.
3.	Dark, bituminous shale	1 foot 10 in.
4.	Coal	2 in.
5.	Fire clay merging into sandstone	3 feet 8 in.
6.	Light gray shale	10 feet.

The fire clay (No. 5) is light gray and very silicious. The lower part of the stratum is a peculiar mixture of fire-clay and sandstone called "gannister rock." If thoroughly tested it will doubtless be found suitable for the lining of Bessemer and other steel converters. The shale (No. 6) when weathered, is very plastic and can be made into stoneware. Its analysis, according to Kramer, is as follows:

Silica (total)	73.20	
Alumina	13.38	
Clay base and sand		86.58
Magnesia	1.01	
Lime	.97	
Ferric oxide	2.19	
Fluxes		4.17
Moisture and volatile		9.25

This clay was used in a roofing tile factory at Covington, about 1886, but, according to Mr. Donaldson, one of the proprietors, it did not give satisfaction, as it cracked badly when burned hard enough to withstand the action of frost. It is said to be one of the best modelling clays in the country.

Along the bottoms of Coal Creek on the land of J. W. Shuster (N. E. ¼, Sec. 19, Tp. 20 N., R. 7 W.) one-half mile southwest of Stone Bluff, is an outcrop of a light gray potter's clay of a superior quality. It is wholly free from grit and has the greasy feel which the better grades of such clays possess. Its analysis, as made for this report by Prof. Lyons, shows the following composition, which compares well with the standard average of such clays used for stoneware and similar products, as given on p. 48.

Clay base and sand	93.07
Fluxes	6.73

At the point of outcrop it is overlain with soil and yellow clay six feet in thickness; the stratum of clay being exposed to a depth of five feet, but its total thickness is as yet undetermined. In the bluffs near by it is found beneath twenty feet of soil and sandstone. The I. & I. C. Railway passes within eighty rods of this deposit. The clay is found over an extensive area north and northwest, having been exposed in wells on the lands of Wm. Mallett and Albert Boord.

On the land of Frank Landers (N. W. ¼ Sec. 19), one-half mile west of Stone Bluff, the same stratum outcrops in several places. It is known to be eight feet thick, and in some places is overlain with a thin vein of coal. Mr. Landers had a sample of the clay analyzed, with the following results: *

Clay base and sand	92.24
Fluxes	8.36

The Hillsboro Pressed Brick Co. has recently acquired a tract of land just south of the town of that name, in Sec. 12, Tp. 19 N , R. 7 W., on which is found a surface stratum of silicious, ochery clay, which is being utilized in making red front brick. The deposit is a remarkably pure one, to be found on the surface in the drift region, and resembles closely

*For complete analysis see table at end of chapter.

the residual surface clays of southern Indiana. The works of the company have been erected on a tract of low ground near the bed of Coal Creek and the clay is secured from the top of the adjoining bluff, the face of which discloses the following section:

1.	Soil and yellow ochery clay	9 feet.
2.	Drab, arenaceous shale	3 feet.
3.	Reddish sandstone	12 feet.
4.	Gray arenaceous shale (micaceous)	3 feet.
5.	Sandstone	—

The dry pressed brick made from the clay (No. 1) are a handsome shade of dark red, but are much more friable than those made by other companies from argillaceous shale.

The two shales (Nos. 2 and 4) are mixed and burned into a fair quality of buff, pressed brick. They are too highly silicious for vitrified products.

In the immediate vicinity of Veedersburg are found the most notable shale deposits of Fountain County. Before the great value of shales for making vitrified products was fully understood, the Wabash Paving Brick Company, now the largest concern of the kind in the State, had located a plant one-half mile southwest of Veedersburg (S. E. ¼, Sec. 12, Tp. 19 N., R. 8 W.), close to the lines of the T., St. L. & K. and I. & I. C. Railways. Here they began making pavers from a fire clay which outcropped in the hill to the west. This clay gradually merged into sandstone as it passed back under the hill, until finally it became too silicious for use.

The company had meanwhile experimented with shales, and finding them highly suitable for their purpose, began procuring them from two different places. Their main supply is now gotten from a bank one mile north of Veedersburg by the side of the I. & I. C. R. R., and is hauled in cars to the factory. A section at this pit shows as follows:

1.	Soil and drift clay	1 foot 6 in.
2.	Blue plastic clay	3 feet.
3.	Dove colored, rotten shale	5 feet.
4.	Blue argillaceous shale with small kidney iron nodules	11 feet 2 in.
5.	Coal	2 feet 6 in.
6.	Fire clay (exposed)	5 feet 4 in.

Of these all above the coal, except about one foot of soil, are mingled in the proportions in which they occur in the bank. Six car loads of this mixture, costing at the plant about 22½ cents a ton, together with forty or more wagon loads from the southern pit are used each day. Fire clay (No. 6) is a dark, plastic clay of fair refractory properties. It will probably be used in the future mixed with the shale, in the proportions of about 1 part to 4.

South of Coal Creek, near the middle of Sec. 13, Tp. 19 N., R. 8 W., is one of the purest beds of shale in proportion to its thickness which has come to my notice in the State. It is on the land of Richard Hetfield, and is the one from which the Wabash Paving Company draws part of their supply. (See frontispiece.) When last seen by me. in September, 1895, it had been mined back until exposed for a depth of more than 40 feet, as follows:

1.	Surface soil and drift	2 feet 8 in.
2.	Blue argillaceous shale – the upper 3 feet discolored by leachings from the soil	35 feet.
3.	Coarse grained arenaceous shale	3 in.
4.	Blue shale, same as No. 2 (bottom concealed)	2 feet 10 in.

This is a rather soft, dark blue shale of very fine texture. The deposit is very homogeneous, being almost free from the concretions of iron carbonate so commonly found in such strata. But one of these was seen which had been thrown aside, and, according to the workmen, not over two a month are disclosed. The silicious band near the bottom was exposed the full length of the cliff, and was the only portion unfit for vitrified products. From the mixture of this shale with that from the bank last noted, the "Poston Block," so many of which have been used in northern Indiana during the past two years, are made. An analysis of a sample, composed of a mixture from the inside of three unburned blocks, shows the following composition of the material entering into their structure: *

Clay base and sand	82.38
Fluxes	14.73

This shows the presence of 2.40 per cent. less of refractory material, and 1.51 per cent. more of the fluxes than the standard average of Ohio shales. This is probably due to a large admixture of the surface soil and clay from the pit north of Veedersburg. Nevertheless, the mixed materials showing the above composition stand up well until thoroughly vitrified, and produce a strong and durable paving block.

Southeast of Veedersburg, on the land of Miles Marshall (N. W. ¼ Sec. 17, Tp. 19 N., R. 7 W.), a bold bluff of the same stratum of blue shale as that worked on the Hetfield land, rises abruptly from the margin of the north side of Coal Creek. The top of the bluff is covered with from 3 to 6 feet of gravel suitable for road material. The shale then sets in and is exposed for 38 feet to the water, beneath which the foot of the bluff is hidden. It is remarkably uniform in color and structure throughout the exposure, the only impurity noticeable being two thin layers of ironstone near the center. (See accompanying illustration.)

* Noyes, chemist: For complete analysis see table at end of this chapter.

SHALE BLUFF ON COAL CREEK, FOUNTAIN COUNTY, INDIANA. ONE MILE SOUTHEAST OF VEEDERSBURG.

One fourth of a mile nearer Veedersburg, on the land of Wm. Dice (S. W. ¼ Sec. 8), the same shale is found in abundance, and can be easily secured by removing three feet of surface stripping. There is also a conspicuous shale bluff on the south side of Coal Creek near the middle of Sec. 17, Tp. 19 N., R. 7 W., and another at the mouth of Clifty Creek in Sec. 15, Tp. 19 N., R. 7 W. At the latter place the shale outcrop is 30 feet thick, and rests unconformably against a sandstone at the eastern end of the bluff.

In a ravine a short distance southeast of the shale bluff belonging to Mr. Marshall is an outcrop, three feet in thickness, of a peculiar surface drift clay. It is light brown in color, and when wet the most tenacious material I have found among Indiana clays. When dry it becomes exceedingly hard, and "sets" like plaster of Paris. It has all the properties of a most excellent modelling clay.

Numerous other deposits of clay, which are suitable for manufacturing purposes, occur in the vicinity of Veedersburg, but the above are all that can be noted in this connection. Three railroads pass through the town, connecting it directly with some of the most important commercial centers of the United States. With such superior facilities for transportation, and with an unlimited supply of excellent shales in the immediate neighborhood, nothing but a lack of energy upon the part of its people should prevent the town from becoming the seat of important clay industries.

One mile south of Covington, on the land of the Hon. Enos Nebeker (S. ½ N. W. ¼ Sec. 1, Tp. 19 N., R. 9 W.), the following strata are exposed on a hillside facing the north:

1.	Soil and drift clay	3 feet 4 in.
2.	Drab argillaceous shale	8 feet 6 in.
3.	Dark bituminous shale	2 feet.
4.	Coal	1 foot.
5.	Fire clay	1 foot 6 in.
6.	Light gray silicious shale (exposed)	8 feet.

Of these, Nos. 2 and 5 are good commercial clays and can be made nto many kinds of products. No. 6 is too silicious to be used alone, but united with the others will increase their value for certain purposes.

Farther south, on land formerly owned by Monroe Carwile, potters clay of a good quality is found in an outcrop exposed for a thickness of three feet. An analysis of this clay by Kramer showed its composition to be as follows:

Clay-base and sand	91.02
Fluxes	4.90
Moisture and volatile	4.08

At an abandoned coal mine on the land of Peter Anderson (S. ½ of S. W. ¼, Sec. 12, Tp. 19 N., R. 9 W.) a deposit of blue-gray argillaceous shale five feet in thickness overlies thirty inches of coal, beneath which is a vein of fire clay the thickness of which has never been determined. Both shale and fire clay are of good quality, and mined in connection with the coal, will well repay the working.

In the S. E. ¼ Sec. 18, Tp. 19 N., R. 8 W., a blue shale comes near to the surface over a large area of land owned by J. C. Graham. It is 6 feet thick at the outcrops and according to Kramer is of the following composition:

Clay-base and sand	84.14
Fluxes	12.17

Beneath this shale are two thin seams of coal separated by a stratum of a fair quality of fire clay 3 feet in thickness.

On a small tributary of Coal Creek in Sec. 3, Tp. 19 N., R. 8 W., is an exposure of gray argillaceous shale 35 feet in thickness. Beneath this is a seam of coal 3 feet 8 inches thick, and below the coal a stratum of fire-clay of unknown depth. Both shale and clay are well suited for manufacturing purposes. Southwest of this, close to the Parke County line in Sec. 36, Tp. 19 N., R. 8 W., occurs a deposit of the better grade of potters clay.

On Sugar Mill Creek (Sec. 25, Tp. 18 N., R. 7 W.) at the lower end of the "Narrows" a blue-black argillaceous shale outcrops in places along the bluff and a well-section one-fourth mile east of the creek shows the shale to be 35 feet thick.

The above comprise all the clay deposits of note found in Fountain County of which I have a knowledge. When the means and time become available for a careful and detailed survey of each congressional township in the county others will doubtless be brought to light. Many of the above are situated by the side of or within easy reaching distance of the four railways which pass through the county. All such will soon repay the investment of capital necessary for their development, provided practical and experienced clay workers are put in charge of the plants which may be erected.

VERMILLION COUNTY

comprises a strip of territory thirty-six miles long and about seven miles wide, lying west of the Wabash River, and south of Warren County, the State of Illinois forming its western boundary. Its total area is 249 square miles, all of which is included in the *Coal Measure* formations. Of this area about one-third is taken up by the terraces and lowland bottoms of the Wabash and its tributaries. The remainder is upland, the eastern border of which is formed by the high bluffs, 120 feet or more above the level of the river, and approaching it closely between Hillsdale and Newport, the county seat.

It is along these bluffs at the point where they meet the terraces, that the largest and most available deposits of under-clays and shales are exposed. The Chicago & Eastern Illinois Railway, running north and south the full length of the county, and close to its eastern border, has its road bed within a mile and a half of all the principal clay exposures. Two other railways, the Toledo, St. Louis & Kansas City, and the Indianapolis, Decatur & Western cross the county from east to west in close proximity to large clay beds, so that the railway facilities are of the best.

Beginning with the southeastern corner of the county, we find along the bluffs between Clinton and the mouth of Brouillet's Creek in Vigo County, numerous outcrops of the same bed of shale as is worked by the Terre Haute Brick and Pipe Co. (full mention of which is made further on in the report on the clays of Vigo County.) Should a railroad ever be constructed on this side of the river these shale deposits will prove valuable. Until then, they, with the underlying coal, will remain practically undeveloped.

One and one-half miles northwest of Clinton on the S. E. ¼, Sec. 9, (14 N., 9 W.), the Clinton Paving and Building Brick Co., erected in 1893 a large factory for the manufacture of vitrified brick from the shales of the vicinity. The principal deposit of shale used lies 100 yards south of their plant, where, at the time of my visit, the following section was exposed:

1.	Soil	1 foot 4 in.
2.	Yellow drift clay	4 feet 6 in.
3.	Drab argillaceous shale	6 feet.
4.	Blue argillaceous shale	26 feet.

Of these, No. 3, while of good quality, is rotten and shelly, breaking up readily into small quadrangular pieces. The main stratum of shale (No. 4) is a soft, smooth and unctuous material, wholly free from grit, and with a smaller percentage of free silica than is possessed by the average of such shales. At a distance of twelve feet from the top of this bed is the first of five bands of rectangular pieces of iron carbonate one and one-half inches thick. These bands occur at intervals of six inches and are seen entirely around the pit. Running obliquely through the stratum of blue shale, as far as exposed, are two or three narrow curved faults or fissures, in which a material much smoother and more unctuous occurs. This corresponds to the iron sediment found in similar faults at the shale pit of the Indiana Paving Brick Co., north of Brazil, Clay County.

Brick made of the material from this pit alone are apt to shrink too much in burning and to be too brittle, owing to the lack of silica. Mixed with a more silicious material, the blue stratum is capable of being made into a strong, hard brick, with a very low power of absorption. The company formerly used the yellow drift-clay overlying the shale in another part of their yard, in the proportions of three-fourths of the shale to one-fourth of the clay. Later, they hauled from a point on Norton's Creek a shale (to be described hereafter) which they mixed in equal proportions with the No. 4 of their pit. The hauling proving too expensive they finally hit upon a shale deposit one-fourth of a mile east of their works which, when mixed with the No. 4, gives good results.

An average sample of this mixture as now used was analyzed by Prof. Noyes, and the composition found to be as follows:

Clay base and sand	84.29 per cent.
Fluxes	14.32 per cent.

This shows a very close approximation to the standard average composition* of such clays, and proves the mixture well fitted for the purpose to which it is put.

South of the plant of this company, in the N. E. ¼ Sec. 16 (14 N., 9 W.), a bore for coal was put down in the summer of 1895. The first vein, 3 feet 3 inches thick, was found at a depth of 65½ feet from the surface. Of this thickness 41 feet was composed of shale, 32 of which was of the better quality for making vitrified products. A shaft has since been put down to the second vein of coal, which lies 142 feet below the surface and is 5 feet 10 inches thick.

On Norton's Creek, 2½ miles northwest of Clinton, a large outcrop of shale is exposed by the side of the switch running from the C. & E. I. Railway to the mine of the Norton Creek Coal Company. This shale comes close to the surface at many places in the N. E. ¼ Sec. 5 (14 N., 9 W.) and S. ½ Sec. 32 (15 N., 9 W.). It contains more free silica than that nearer Clinton. As mentioned above, it was for some time mixed with the blue shale at the pit of the Clinton Paving Brick Company. Care must be taken, however, in mining it, as in some places the beds contain numerous rounded nodules of iron carbonate. These, when broken open, show a formation of concentric layers, surrounding a nucleus

* See page 54.

of some foreign body, about which is more or less calcite, or crystalline carbonate of lime, and iron sulphide or pyrites. The latter impurity, when ground up with the shale in any quantity, is very harmful, causing the fluxing to take place at a temperature below that at which thorough vitrifaction occurs. If these concretions be carefully gleaned from the shale, the latter will be found in every way suitable for vitrified products. This shale lies from 10 to 12 feet below the seam of coal which has been worked to some extent in its immediate vicinity. Separating the two are 4 feet of a good quality of under-clay and from 4 to 6 feet of sandstone, the latter lying on top of the shale. A switch being already in place, this is an excellent location for a factory for vitrified brick or sewer pipe.

Farther north, along the margins of the bluff between Clinton and Hillsdale, are numerous outcrops of shale and underclay of good quality and within easy reaching distance of the C. & E. I. Railway. North of Hillsdale the bluffs come close up to the lowlands or overflowed bottoms, a narrow terrace only intervening, along which the roadbed of the railway is built.

In a ravine on the land of Jos. Burns (S. W. ¼, Sec. 26, Tp. 16 N., 9 W.), a short distance west of the station of West Montezuma, the following connected section was obtained, which shows the presence of a remarkable variety and quantity of high grade commercial clays:

1.	Soil and drift	5 to 7 feet.
2.	Sandstone	2 to 10 feet.
3.	Light gray arenaceous shale	1 to 6 feet.
4.	Coal	3 to 5 feet 6 in.
5.	Fire-clay	3 to 4 feet.
6.	Blue to drab argillaceous shale	25 to 30 feet.
7.	Concretionary iron carbonate (two bands)	6 in.
8.	Black fissile shale	2 to 3 feet.
9.	Coal	1 foot.
10.	Fire-clay (white silicious)	5 to 7 feet.
11.	Blue and drab argillaceous shale	42 feet.
12.	Black fissile shale	2 feet.
13.	Coal	1 foot 8 in.
14.	Fire-clay	8 feet.

Of these Nos. 3, 5, 6, 10, 11 and 14, aggregating from 84 to 89 feet of workable clays, and Nos. 4, 9 and 13, comprising 4 to 7 feet of fuel suitable for their burning, are found in the one place. Near the mouth of the ravine Mr. Burns, in 1872, erected a plant and began the making of fire brick from the clay No. 10. A switch from the C. & E. I. Railway runs to the plant, while the I., D. & W. Railway, one mile south, furnishes direct connection with all eastern and western points.

The gray arenaceous shale (No. 3) overlying the top vein of coal is, in places, cut out by the sandstone, the latter resting directly upon the coal. In such places the coal is much thinner than where the shale forms its roof. This shale can be made into pressed front and ordinary brick, and, mixed with some of the lower deposits, into vitrified products. The coal (No. 4) of the section has been mined at numerous places in the vicinity, and furnishes the fuel for the burning of the fire-brick at the plant below. It is a "semi-block" coal and burns into a white ash with no clinkers The fire-clay (No. 5) is a soft, dark plastic material containing *stigmaria* and other remains of plant fossils. It vitrifies to a dark brown, and one or two kilns of sewer pipe of good quality were made from it some years ago, as an experiment, by Mr. Burns. These were sold to the I., D. & W. Railway and are now in use along that line in the vicinity of Montezuma.

Stratum No. 6 is a dark blue shale or "soapstone," which weathers to a lighter drab in places. It burns to a close textured body of a handsome dark red color. Its composition, according to analysis by Prof. Lyons, is as follows:

Clay base and sand	81.24 per cent.
Fluxes	15.91 per cent.
Volatile	2.87 per cent.

This compares favorably with the standard composition (see p. 54) of shales used for vitrified products, and shows, as far as a chemical analysis can, the fitness of the shale for making such products.

Near the lower part of this stratum of shale are the two bands of iron carbonate (No. 7 of the section), the upper being 6 inches thick and the lower 2 inches, the two being separated by a stratum of the shale 14 inches in thickness. The pieces of ironstone are quadrangular and have the appearance of bricks laid regularly in place.

Fire-clay No. 10 is nearly white and contains so large a percentage of silica that it resembles in appearance a sandstone. It is the most refractory underclay that has been discovered in the State, and the fire-brick and furnace linings made from it have been put to the most severe tests possible, and have everywhere given the best of satisfaction. Large numbers of the brick are sold annually to iron manufacturers, as far west as Montana and south to Georgia and Alabama. In a kiln at Burns' factory, which has been in constant use for 22 years, the brick of the floors and walls are of this clay and appear little the worse for wear. An analysis of this clay by Prof. Lyons shows the following percentage composition:

Clay base and sand	98.24 per cent.
Fluxes	1.79 per cent.

From this it will be seen that the clay is of high refractory grade, and moreover, very pure. It contains less fluxes than any plastic underclay so far discovered in Ohio, and lacks but .02 per cent. of being as pure as the Mineral Point flint clay of that State, which is largely used in making high grade refractory material, such as glass pots and kindred products. This stratum of clay underlies an area a mile wide and extending from Hillsdale almost to Newport. It is at present worked only by Burns and Hancock, and by the Hillsdale Fire Brick and Tile Company, whose plant is located one mile south, near the crossing of the I., D. & W. and C. & E. I. railways. Both companies grind and ship large quantities of the fire-clay, receiving therefor $1.50 a ton on board the cars. This is used for making mortar for laying and setting the parts of kilns, for rock and adamant plaster, and many other purposes.

Shale No. 11 is the correlative of No. 7 of the section obtained on the Morgan land across the river.* At Burns' its upper half contains much more free silica than the lower, and in places, especially farther north, is replaced by a compact gray sandstone. The lower half is the soft, unctuous, argillaceous material so well fitted for vitrified products. An analysis by Prof. Lyons of a sample of the latter shows its composition to be as follows:

Clay base and sand	88.06 per cent.
Fluxes	11.88 per cent.

This is a purer and more refractory shale than No. 6. By itself it will evidently shrink some in burning, but by mixing with the upper half of the same stratum a material can be obtained whose chemical composition is in every way suitable for making the best of vitrified products.

This stratum of shale is found exposed for a distance of twenty feet by the side and within thirty feet of the kilns of the Hillsdale Fire Brick Company. Fifty or more car loads of it were shipped from there to Chicago and made into roofing tile. It brought thirty cents a ton on board the cars.

Nos. 12, 13 and 14 of the above section are beneath the surface level at the site of the plant of the Montezuma Fire Brick Company, and were given me by Mr. Burns from a record of a well boring. One mile southwest of Hillsdale these three strata outcrop on the land of Mr. Yoke. Here the bottom of shale No. 11 rests on four feet of fissile black shale, beneath which the coal is ten inches thick. The underclay of this coal, eight feet thick, is a fine grained, light colored silicious material, which, when free from mpurities, will make good stoneware. Mr. Yoke has for some time made from it a patent "stone" fence post, and has proven the clay to be refractory enough to stand up under the heat required for glazing. Beneath this fire clay is still another vein of coal two and one-half feet thick which has been mined in a number of places southwest of Hillsdale.

Taking into consideration the quality of the fire clay (No. 10) and the variety and abundance of the shales, together with the presence of a

*See above, p. 51.

clay suitable for potter's use, and coal sufficient to burn them all, I consider the deposits at West Montezuma to be the most valuable found in western Indiana.

The sequence of the strata given above, when taken in connection with that of those found outcropping in the bluffs on the Morgan land in Parke County, show conclusively that the beds of shale, clay and coal were once continuous and unbroken across the Wabash Valley. A mighty force it has taken, acting unceasingly through hundreds of centuries, to erode this valley two and one-half miles wide to its present depth.

West of Newport, along the Little Vermillion River, outcrops of large deposits of good clay are noticeable in a number of places. In the S. E. ¼ Sec. 30, 17 N., 9 W., is an exposure of 35 feet of light gray argillaceous shale near the site of White's old mill. A short distance below this, on the north side of the stream, there is a deposit of shale that might be worked to good advantage in connection with the sandstone which lies in the shale bed. The sandstone varies from 12 to 15 feet in thickness and is overlain by 6 to 10 feet of dull gray argillaceous shale and underlain by 15 to 20 feet of a better quality of fire clay and blue shale. At the "horse shoe bend" of the same stream (Sec. 29, Tp. 17 N., R. 10 W.) are also exposures of large beds of both shale and underclay which will repay working should a railway ever be built near them.

Northwest of Newport the Wabash River terrace widens out until in places it is four miles in width with an average elevation of almost forty feet above the overflowed bottom land. Along the western border of this terrace or prairie the outcrops of shale and clay, with their accompanying coals, occur in many places. But one of these has been utilized, and that by the Cayuga Press Brick and Coal Mining Co., in the N. E. ¼ Sec. 7, 17 N., 9 W. At this point, one and one-half miles southwest of Cayuga, the largest plant now in the State for the making of pressed-front brick has been erected and a switch of the T., St. L. & K. C. Railway constructed thereto. The deposits of clay used are found seventy-five yards from the dry pans and are hauled into the sheds adjoining by tramway cars. An average section of the pit discloses the following strata:

1.	Soil and drift clay	2 feet.
2.	Pinkish shaley sandstone	5 feet.
3.	Drab arenaceous shale	5 feet 6 in.
4.	Blue arenaceous shale	7 feet.
5.	Bastard fire clay (bottom concealed)	6 feet.

The sandstone, No. 2, merges gradually into shale, No. 3, so that the latter contains a large quantity of free silica and numerous scales of mica, not enough, however, to prove harmful. The two shales, Nos. 3 and 4, are mixed together in varying proportions to form different shades of red. Average samples, taken from the centers of several unburned brick, which were made of the two shales mixed in equal proportions, were analyzed by Professor Noyes, and the composition found to be:

Clay base and sand	86.55 per cent.
Fluxes	13.78 per cent.

This mixture burns into a tough, even grained, front brick of a handsome and uniform shade. Its composition shows it to be well suited for the making of vitrified products.

Stratum, No. 5, has the general appearance of an underclay, being unlaminated, and of the light gray color usually possessed by such deposits. Its chemical analysis proves it, however, to be of low refractory power. Professor Noyes analyzed an average sample and found it to contain of

Clay base and sand	84.06
Fluxes	12.40.

This clay burns into a buff front brick of handsome appearance. Just why it should burn buff when the analysis shows the presence of 7.01 per cent. of iron oxide, is a chemical problem which is difficult to solve. At the exposure west of the plant of this company the layer of sandstone overlying the shale is much thinner, and the latter is seen to have a strong dip to the southwest and to be much contorted in the bed. One-half mile south the shale has been proven by bore to be thirty feet thick, with a surface stripping of but two and one-half feet.

The above comprise some of the more available deposits of commercial clays which came to my notice in Vermillion County. Many others doubtless exist. Those mentioned are sufficient in quantity and in quality suitable to make for centuries many of the products which are now brought into Indiana from other States.

VIGO COUNTY,

in which the city of Terre Haute is situated, comprises an area of 400 square miles, and lies on the western border of Indiana and almost midway between the north and south boundary lines of the State. The Wabash River flows in a southwesterly direction through the county, and numerous small streams, which rise in the uplands, find their way into it in such a manner as to furnish an abundance of running water to every township. The surface of the county is practically level, the topography not being marked by any prominent hills or rugged scenery, and may be divided into three general divisions, viz.: River bottoms, prairies and uplands.

The river bottoms, which are usually overflowed each spring, are from two to four miles in width. Bordering these lowland bottoms are level river terraces or prairies varying in width from three to eight miles. Beyond the terraces are the uplands, usually more or less broken by the erosion of small streams. These extend to the confines of the county and are underlaid with coal. With the exception of the recent sedimentary clays of the river bottoms, all the commercial clays of the county are found in the uplands, or outcropping along the hillsides where the river terraces meet the uplands.

The largest and most available deposits are found in an area (two miles wide) of the upland on the west side of the Wabash River and north of the old National Road.

The following section, obtained at Broadhurst's mine, one mile west of Macksville, in the S. E. ¼ of the S. E. ¼, Sec. 24 (12 N., 10 W.) may be taken as showing the average sequence and thickness of the strata over the greater portion of the area mentioned:

1.	Soil and drift clay	13 feet.
2.	Limestone (fossiliferous)	2 feet.
3.	Gray argillaceous shale	12 feet.
4.	Sandstone (massive)	12 feet.
5.	Shaly sandstone merging into blue shale or "soapstone"	42 feet 6 in.
6.	Coal	4 feet 8 in.
7.	Fire clay (not passed through)	6 feet.

The lower two-thirds of stratum No. 5 is the blue shale or soapstone found in the uplands on both sides of the river. That portion of it suitable for vitrified products or dry pressed brick, varies in thickness from 15 to 35 feet, the former being the minimum amount which can be relied upon. Passing upward this shale merges gradually into the sandstone, No. 4. In a few places, as along the roadside in front of Mr. Bennett's house, one-third of a mile east of the Broadhurst mine, a thin stratum of non-fossiliferous, bastard limestone is found, separating the sandstone, No. 4, from the overlying shale, No. 3. The latter, No. 3, is usually more or less impregnated with leachings from the limestone, No. 2, and its quality thereby impaired.

One-half mile west of Macksville, and just north of the point where the Vandalia Railway strikes the upland, on the Walker farm (S. W. ¼ Sec. 19, Tp. 12 N., R. 9 W.), is a very large deposit of shale, No. 5, which can be gotten by easy stripping. Professor Cox, in the Geological Report for 1870, mentions this point and gives the thickness of the shale as 48 feet. A switch 100 yards long, from the Vandalia Railroad, would be ample to reach the very center of the deposit. The quality of the shale is fully equal to that at present used by the Terre Haute Brick and Pipe Company. Coal "L" underlies this deposit and is at present mined 100 yards south of the railroad.

Another large outcrop of shale No. 5 occurs on the Larrimer land in N. W. ¼, Sec. 25 (12 N., 10 W.) It is in a ravine one-eighth of a mile northwest of the coal mines which are worked on the same land. This shale can be secured by easy stripping. Some of the most handsome and durable pressed front brick that have ever come to my notice were made from it for Dr. J. T. Scovell of Terre Haute. This deposit outcrops over quite an area, is underlaid with coal, and can be easily reached by a switch from the Vandalia, one mile distant.

Along the low bluffs of West Little Sugar Creek on the Hickling land, in the north ½ Sec. 15 (12 N., 10 W.), is an extensive outcrop of the same shale which is exposed for a thickness of 20 feet. It is overlain with 7 feet of soil and yellow clay and underlain with bituminous coal. A switch one and one-half miles would be necessary to reach this deposit.

On the "old Casto farm," now owned by H. T. Thorp of Terre Haute, in the S. E. ¼ Sec. 23 (12 N., 10 W.), is another extensive outcrop. This is within one-third of a mile of the Vandalia Railway and by the side of Sugar Creek, in which is found a never-failing supply of water. A vein of coal 5 feet thick is found at a depth of 50 feet and another at 130 feet. The shale is exposed to a depth of 12 feet, beneath 4 feet of overlying soil and clay. It is a soft, light gray, unctuous material, wholly free from grit or pyrites, easily cut with a knife, and very plastic when ground and moistened. Sample paving brick have been made from it which were very tough and almost non-absorbent. The shale, according to analysis by Prof. Noyes, has the following composition:

Clay base and sand	90.65 per cent.*
Fluxing impurities	9.87 per cent.

Comparing this with the standard average of shales suitable for vitrified products, given on page 54, as follows:

Clay base and sand	84.78 per cent.,
Fluxing impurities	13.22 per cent.,

we find it to be a much purer and more refractory clay than the average, and it will therefore have a tendency to shrink in burning, which can be readily overcome by mixing with it some of the overlying surface clay or a shale containing more silica. This analysis may be taken as fairly representative of the average composition of these soft gray, unctuous shales found in the uplands west of the Wabash River.

The Terre Haute Brick and Pipe Company has recently purchased 200 acres of land 2½ miles northwest of Terre Haute in Sec. 18 (12 N., 9

* For complete analysis see the table at end of chapter.

W.), almost all of which is underlain with shale and coal. Just above the high water mark of the Wabash River, and a few hundred yards south of where the Indianapolis & St. Louis Railway strikes the uplands, this company erected, in 1894, a modern plant for the making of hollow brick and vitrified wares. At this point the shale overlying the coal outcrops, and the latter is secured through a vertical shaft at the depth of 34 feet. The strata exposed are as follows:

1.	Surface and drift	1 foot 6 in.
2.	Gray argillaceous shale, "soapstone"	30 feet.
3.	Black fissile shale	2 feet 6 in.
4.	Coal "L"	5 feet.
5.	Fire clay	9 feet.

The shale (No. 2) is the same stratum as No. 5 of the Broadhurst section. It has the general character and composition of that found in the deposits mentioned above. At the pit, where it had been exposed to the depth of 20 feet, it was seen to lie in laminae 1½ to 4 inches in thickness. Two bands of iron carbonate (siderite) in large concretionary nodules were found in the exposure. They were easily separated and thrown aside by the miners. The shale vitrifies to a handsome dark red color. The body of the hollow brick made from it is exceedingly solid and close textured, and there is no doubt but that it will make vitrified products of a high grade. The fire clay beneath the coal has been used for brick for the walls of kilns, and has fair refractory properties. Mixed with the shale it can all be utilized in the various products made by the company.

Farther north thick beds of the shale overlying coal "L" outcrop at a number of localities. At Durkey's Ferry in the N. W. ¼ Sec. 21 (13 N., 9 W.), it is 18 feet thick, and contains many ironstone nodules, some of which when split open disclose very fine impressions of fossil plants.

On the east side of the Wabash River the principal outcrops of commercial shales found at available points are southeast of Terre Haute in Riley and Honey Creek townships. On the land of Hon. J. M. Sankey (N. E. ¼ Sec. 17, 11 N., 8 W.) the E. & I. Railway runs by the side of a large deposit of soft, gray argillaceous shale. This is more than 20 feet thick and lies just above coal "M", which at this point is three feet in thickness. The shale will require little stripping and can be used for all kinds of vitrified products. It contains less than an average amount of free silica, and the shrinkage in burning will, on that account, be considerable, but this defect can be readily overcome by mixing with surface clay or some more silicious material. The eastern one-half of section 17 is underlain with this shale, and the coal beneath it. At a depth of 106 feet coal "L" with its overlying blue shale is found, and is mined just west of Riley. The Sankey deposit, having already present the raw material, fuel and railway, is a most promising place for the location of a clay industry.

On the "old Tuller farm" in the N. W. ¼ Sec. 13 (11 N., 9 W.) is a bluff of shale 30 feet in thickness. The point where found is one-half mile north of the E. & I. Railway, to which a level tramway could be readily constructed and the shale hauled to it, or a switch built and a plant erected by the side of the deposit. The shale is of good quality and contains a higher percentage of free silica than that at Sankey's. Coal has not been found here, but borings will undoubtedly show the presence of vein "M" immediately below the shale. Numerous other exposures of shale suitable for manufacturing purposes occur farther south and east, the two mentioned being the closest to railway facilities.

The Terre Haute Pressed Brick Company has been making for two years a good grade of dry-pressed front brick from the sedimentary clays found in the lowlands of the Wabash River. The plant of the company is situated on the border of the eastern river terrace, in the northwestern part of the city of Terre Haute, and the clays used are obtained 200 yards west of and 35 feet below the level of their yard. The clay has been deposited where found by the high waters of the annual overflows. Its thickness has never been determined, but it is known to be more than 20 feet. It is very fine in texture, and for a river-bottom clay remarkably free from pebbles and coarser impurities. The dry-pressed bricks made from it are very hard and smooth.

The one bad feature about this clay is its tendency to burn into different colors. This necessitates much labor in the assorting of the finished product. No less than thirteen different shades are gotten from each kiln. This is doubtless due, in part, to the non-uniformity of chemical composition which such a clay must of necessity, possess, but more largely to the variations of the burning and positions in the kiln. Nevertheless, by careful assortment, the company has been successful in getting a good percentage of first-class brick, and the "seconds" sell readily at fair prices for sidewalks and foundations.

This sedimentary clay is the sole material used in the eight or ten million soft mud brick made annually at Terre Haute. These give good satisfaction, and the clay seems in every way suitable for their production. At Middleport, Ohio, similar sedimentary clays from the lowlands of the Ohio River, are used by two large factories for the making of vitrified brick. They present the cheapest form of clay which can be used for paving material, as they can be dug by steam shovel for a nominal cost, and the labor necessary to prepare them for use is almost nothing. On the other hand the excessive plasticity of the material is against it, as it is difficult to prevent faults of structure in forming the brick.

The analysis of the Terre Haute clay (Noyes, chemist) is here given side by side with that of a similar sedimentary clay from the lowlands of the Ohio River, near Columbia, Ohio, and which, according to Orton, "was worked into vitrified wares of high grade":

	TERRE HAUTE.		COLUMBIA, OHIO.	
Silica (total)	66.11		63.73	
Alumina	13.78		17.17	
Water (combined)	6.34		4.90	
Clay-base and sand		86.23		85.80
Oxide of iron	5.35		5.85	
Lime	1.67		.58	
Magnesia	1.78		.97	
Potash	2.11		2.33	
Soda	1.15		.67	
Fluxes		12.06		10.40

At the mines found in Vigo County along the Vandalia Railway, east of Terre Haute, but little clay or shale suitable for manufacturing purposes was observed. At Seeleyville the section exposed in the shaft of the new "Ray" mine of the Vigo County Coal Company disclosed, instead of the argillaceous shale usually found above the worked seam of coal, 41 feet of arenaceous shale. This contained too high a percentage of silica and mica to be of value. The underclay of the coal is but 18 inches thick. A lack of time prevented my visiting the mines farther north along the I. & St. L. Railway, but from the records of bores furnished me by the Coal Bluff Mining Company I should judge the conditions there to be about the same as at Seeleyville.

The deposits of Vigo County clays mentioned above are all valuable, and a factory located at any one of them will, under normal conditions, prove a paying investment. The city of Terre Haute will doubtless maintain in the future, as it has in the past, a steady, onward growth, and will use clay products for buildings and roadways to the value of many millions of dollars. With large deposits of the raw materials suitable in the highest degree for making these products; with the best of fuel for burning these materials into their proper shapes, and with seven railways stretching in all directions, ready at a moment's notice to carry the surplus to less favored cities, there is no reason why a single dollar should be sent elsewhere for such products.

CLAY COUNTY

has long been noted as the mining center of Indiana. Its beds of non-caking block coal are the most extensive found in the United States, and their development, brought about largely by the energy and acumen of a former State Geologist, Prof. E. T. Cox, has added much to the wealth and prosperity of the county. The beds of bituminous coal underlying the western third of the county are also of great economic value, and their working gives employment to many hundreds of men.

Since 1890, however, another industry based upon the clay resources of the county, has come to the front, and bids fair to, in time, outstrip even that of coal mining in importance. Brazil, the county seat, has become, since that date, the leading clay manufacturing center of the State. Five large companies, each with an invested capital of $40,000 to $100,000, have been formed, and are to-day busily engaged in making from the fire clays and shales of the vicinity many different kinds of clay products. Previous to the date mentioned the clays of Clay County had received little attention. Two potteries, one of which is still in operation, had used the underclay of the vein of coal immediately above the main block seam "I," for making stoneware; and Weaver Bros. had for 21 years made "stone" pumps from the fire clay beneath the latter seam. Other than this no use whatever had been made of a resource which is destined to equal in value that of the seams of coal which it accompanies.

Three or four of the clay manufacturing companies at Brazil conduct their business on a basis at which they can defy competition. Their factories are erected at points where both clay and coal exist, and are readily obtained free from all transportation charges. Railways are used only to ship the finished products. The largest industry whose plant is so situated is that of the Monarch Sewer Pipe Company, whose factory is located one mile northwest of Brazil, in the S. E. ¼ Sec. 25, (13 N., R. 7 W.). This company manufactures sewer pipe, flue linings, etc., from the underclay of the main vein of block coal. The shaft of their coal and clay mine is but a few yards from their main building. A section, to the bottom of the vein of clay used, discloses the presence of the following strata:

1.	Soil and yellow surface clay	12 feet.
2.	Blue drift clay ("hard pan")	7 feet.
3.	Gray argillaceous shale	33 feet.
4.	Coal (top or "rider" vein)	2 feet 3 in.
5.	Fire clay (potter's clay)	3 feet 2 in.
6.	Blue argillaceous shale	19 feet.
7.	Dark fissile shale (bituminous)	1 foot 6 in.
8.	Coal—main block "I"	3 feet 6 in.
9.	Fire clay	5 feet 4 in.

The coal, No. 8, is first mined and then the fire clay is taken up. The latter is a light gray in color, free from sulphur or other impurities, hard when first mined, but weathers after a few weeks' exposure into a fine grained plastic mass. This makes a strong and durable sewer pipe, which with a salt glaze becomes a light reddish brown on the outer surface. Shale, No 6, is a high grade laminated clay, which extends over a wide area between the two veins of coal. A mixture of one-third of it with two-thirds of the fire clay burns to a handsome dark brown color, and makes a sewer pipe of great strength. Shale, No. 3, is also a good product for many wares, especially if mixed with either of the above.

The men in charge of this factory are practical clay-workers of long experience in other States. They state that the block coal found in the vicinity of Brazil can not be excelled for burning clay products. It contains less sulphur than any other fuel and, as a consequence, a better glaze is secured on the surface of all wares. The Monarch Company puts out 1,200 car-loads of products each year, the total value of which is about $90,000.

One-half mile farther north the Brazil Brick and Pipe Company, the pioneer of the new clay industries of central Indiana, has its factory located. Four of the five owners are men whose lives have been spent in clay factories. One of them said: "We tested clays in several different States and those found in the vicinity of Brazil were selected as the best for the business we have in hand. We wanted a clay that would dry quickly without cracking and that would burn safely with a salt glaze. This we have in the underclay of the block coal."

This company mines its coal and clay from a slope shaft, one-eighth of a mile west of their plant, and hauls them to the latter by a tramway. They make of the underclay (No. 9 of the section given above) hollow brick for structural purposes, and vitrified drain tile, to the value of $50,000 annually. By mixing the gray argillaceous shale, overlying the top vein of coal with the fire clay, the company has made both drain tile and hollow brick of a darker and more handsome finish than when made of the clay alone.

The two shales, Nos. 3 and 6, which aggregate 52 feet in vertical thickness at the Monarch Company's shaft, outcrop in many places along the valley of Otter Creek. In a few places No. 3 has merged into a grayish sandrock, beneath which the top vein of coal "K" appears in a vein of varying, but never of workable thickness. The potters clay beneath this coal has been used since 1859 in the pottery at Brazil. When properly washed and tempered it burns into a close textured ware, buff or gray in color according to the intensity of the heat to which it is subjected. This ware is of great strength, and takes a handsome dark glaze with Albany slip-clay. One of the best outcrops of this potter's clay is in the S. E. $\frac{1}{4}$, Sec. 17 (13 N., 6 W.).

WORKS OF BRAZIL BRICK AND PIPE CO., BRAZIL, IND.

WORKS OF CHICAGO SEWER PIPE CO., BRAZIL, IND.

Since 1891 the Indiana Paving Brick Company, whose plant is located in the western suburbs of Brazil, has used the gray shale (No. 3) from an outcrop near the Otter Creek bridge of the I. & I. C. Railway, two miles north of Brazil. At their pit the bed of shale is 30 feet thick and the underlying coal "K" 2½ feet. The shale is gotten by blasting near the base of the worked ledge, when large quantities of it, sometimes 20 tons, come tumbling down. It is overlain with three feet of shelly sandstone, which must be separated and thrown aside. All the rest, including four feet of yellow surface clay, is loaded onto cars on a near-by railway switch and hauled to the factory.

In the exposed ledge the shale is seen to be in laminae or layers from ½ to 2 inches thick. Some narrow perpendicular cliffs or faults were noticed, down which water, impregnated with oxide of iron, had passed, the water in time evaporating and leaving the mineral in thin sheets in the crevices.

At the plant a mixture composed of two-thirds of this shale, one-sixth of surface clay and one-sixth of the blue shale overlying the main block coal, "I," is used in making the paving brick. Many millions of these bricks have been sold in the cities of eastern Illinois, northern Indiana, and especially in Indianapolis. Everywhere they have given the best of satisfaction.

On a switch of the "Midland" Railway, one and three-fourth miles northeast of Brazil, in the N. W. ¼ Sec. 30, 13 N., 6 W., is the plant of the Excelsior Clay Works, erected during the summer of 1895, for the purpose of making vitrified products and stoneware. The clay used will be the underclay of coal "I," which is mined 150 yards northwest of the plant, the potter's clay beneath the "rider" vein and the gray shale overlying the latter. All of these are of the same character as found at other points mentioned above. The potter's clay outcrops five feet in thickness in the ravine a few yards north of the plant. Both fuel and clays will be brought direct to the crushing room by means of tramways.

One mile southwest of Brazil is located the plant of the Chicago Sewer Pipe Company. This company began in 1893 to make sewer pipe from the gray shale (No. 3) overlying the "rider" vein of coal, and find it in every way suitable for their purpose. Their pit is situated 100 feet south of their plant, and the shale is hauled up over an inclined tramway and dumped by the side of the dry pan. It is mined by stripping only the soil, the seven feet of "hard pan" underlying this being used in the proportion of one-fourth to three-fourths of the shale. The stratum of the latter is thirty feet thick. Samples of this shale have been tested for roofing tile by the Wabash Roofing Tile Company, of Montezuma, Ind. Mr. John Donaldson, the superintendent of the company, informs me that it makes a stronger tile and warps less in drying and burning than any material he has tried.

The Chicago Sewer Pipe Company investigated the clays of Iowa, Illinois and Indiana before locating their plant and finally chose the present site as the one where clays of a superior quality for making sewer pipe could be secured at a minimum cost, and where fuel and transportation facilities were of the best. The factory is run to its full capacity, and almost the entire output is shipped to Chicago, the demand being far greater than the present source of supply.

The shale (No. 3) by itself, burns to a dark cherry red; mixed with "hard pan" or surface drift clay, to a brighter red. It has by bores and shafts been proven present on all sides of Brazil to a distance of two miles, except to the southeast, where it seems to be largely replaced by a sandstone. It has an average thickness of thirty feet over the area mentioned, and in most places lies within from twelve to eighteen feet of the surface. The blue shale (No. 6) overlies the middle vein of block coal "I" wherever the latter is found. In some places it contains too large a percentage of pyrites to be of value. The underclay (No.9) is also co-extensive with the block coal "I," and in the immediate vicinity of Brazil is uniform in character and composition with that used in the factories mentioned above.

On the north fork of Otter Creek, in the northern tier of sections of township 13 N., R. 7 W., are numerous outcrops of a blue argillaceous shale in every way suitable for vitrified products. At the shaft No. 8 of the Brazil Block Coal Co. (N. E. ¼ Sec. 3) it is exposed to a depth of ten feet by the side of the railway switch running past the mine. Two seams of block coal are mined at this place. The upper one is overlain with fourteen feet of blue argillaceous shale and underlain with three and one-half feet of fire clay, both suitable for manufacturing purposes. The underclay of the lower vein of coal contains too much sulphur to be of any value. Having the three essentials, raw material, fuel and transportation present, this is a most inviting site for a paving brick or sewer pipe plant.

In the vicinity of Carbon are also large deposits of commercial clays. Of these the ones on the lands of Benj. Simpson have been worked for some time. Here is found a surface yellow clay of great purity, large quantities of which are used by the Encaustic Tile and Terra Cotta Works, of Indianapolis, as a body for red products, it burning into a very handsome shade of that color.

Both of these companies also secure from the Briar Block Coal Company of Clay City, a fire clay which they use as the main body-clay in the production of their wares. The shaft of this company is located one mile northwest of Clay City, on a switch of the E. & I. Railway. The underclay of the main block coal "I," is the material which is mined and shipped. This coal is here found at a depth of 117 feet and the vein is but 3½ feet in thickness. As a consequence, much of the underclay has to be handled to make height. The proprietors have worked up a good market for it, and during the last year sold over 9,000 tons at 90 cents per ton on board the cars. Besides Indianapolis, it was shipped to

PLANT OF BRIAR BLOCK COAL COMPANY, CLAY CITY, INDIANA.

Chicago and Cincinnati, where it was made into ornamental brick, fire brick and terra cotta. It has essentially the same properties as the underclay of similar horizon at Brazil. Its refractory qualities are not as high as those of the clays of Montezuma. When ground and wet it becomes a very close plastic material, well suited for the uses to which it has been put. Immediately above the block coal at this mine are 27 feet of blue argillaceous shale, the upper two-thirds of which can be made into vitrified products.

A stoneware pottery was established at Clay City in 1846, and has been operated continuously since. For many years the clay used was obtained from a pit one-third of a mile farther south in N. W. ¼ Sec. 32 (10 N., 6 W.) The clay is obtained by stripping 6 to 8 feet of soil and surface clay, beneath which it lies in a stratum 5 to 7 feet in thickness. Underlying this is a reddish, rotten sandstone of unknown depth. Crystals of gypsum (selenite) occur in some parts of the clay deposit, but not in sufficient numbers to prove deleterious. This clay is very light in color, and has good refractory properties, its one drawback being that the ware has a tendency to air-crack while cooling. It was formerly used in quantities in a pottery in West Indianapolis; several thousand tons having been shipped there. It brought $1 per ton on board the cars at the pit.

On account of the stripping necessary to get at this clay, the present potter, Beryl Griffiths, has gradually abandoned its use, and now secures his supply of clay from the land of Robt. Guthrie, 3 miles southeast of Clay City, and one-fourth of a mile from the E. & I. Railway. At this point a good potters clay is secured with but little labor from beneath a thin seam of coal, where it is found in a stratum 3½ feet in thickness.

One-half a mile north of Clay City is the mine of Burger & Burnham. The underclay of the worked coal is richer in silica and therefore more refractory than that at the Briar Block mine. Mixed with the potters clay from the land of Guthrie in the proportion of one part to two, it improves its quality for stoneware purposes, producing a strong, close textured product which does not air-crack and which stands up well under great heat.

South of Cloverland, three fourths of a mile, in the bed of a creek on the farm of John Williams, is an exposure of good shale 4½ feet thick. Beneath this is a vein of coal 2½ feet in thickness which has been worked by stripping. At one point where the coal had been eroded some fine examples of "cone in cone" were obtained from the underlying fire clay. These appeared as small cone-shaped masses of the fire clay set one within another. They had the appearance of small concretionary or pressure structures, and were probably caused by the slipping of certain of the hardened fire clay layers.

On the land of Henry Stedman, one and one-half mile west of Staunton, the bituminous coal "L" is mined, the vein in several places averaging 7 feet in thickness. A drift bowlder clay rests directly upon the coal with no shale or slate intervening. Much of the coal may have been eroded by the drift before this deposit of clay was made. "Hard pan", where the term is correctly used, applies to the second layer of drift or bowlder clay, which is usually separated from the first layer by a stratum of sand or gravel. It is usually an impervious stratum of hard blue clay and constitutes the most common water horizon throughout the drift covered area of Indiana.

The above mentioned deposits of clay and shale constitute all which I was enabled to examine personally in Clay County. As has been shown they cover a large area of the county and suitable locations for factories for their utilization are abundant. Those already erected have proven the clays fitted in the highest degree for the making of many products. Their orders during the years 1894 and 1895 in many instances exceeded their output, and the trade has been so far worked up only in small areas of the States of Michigan, Illinois and Indiana. The sewer pipe and paving brick industries were scarcely affected by the panic of 1893-'94, as many cities kept their unemployed workmen engaged in street repair, and so the demand for these products was increased rather than diminished. Taking everything into consideration there is no reason why Clay County should not become as noted for her clay industries in the future as she has been for her deposits of block coal in the past.

OWEN COUNTY.

Occupying an area of 398 square miles, south of Putnam and east of Clay, is Owen, a county rich in undeveloped mineral resources. The Coal Measures form the surface rocks of its western third, the Millstone Grit of its middle third, and the Subcarboniferous of the eastern third.

Within the last named formations are comprised some highly valuable beds of oölitic limestone which are quarried in the vicinity of Romona and Spencer. Three railroads, the Louisville, New Albany & Chicago, the Indianapolis & Vincennes, and the Evansville & Indianapolis cut across, respectively, the northeastern, the southeastern and the southwestern corners, leaving the center and northern parts wholly without facilities for transportation.

The West Fork of White River flows across the southeastern corner and Eel River across the northwestern, these two streams and their numerous tributaries forming an ample system of drainage.

The more valuable deposits of clays and shales are found in the townships 9 and 10 N., ranges 5 and 6 W. Here are located the principal coal veins, in fact the only ones of value in the county. In the immediate vicinity of Patricksburg the main block coal "I" is found close to the surface in thick veins of great purity. On the land of John Andrews, one-half a mile southeast of Patricksburg in the N. W. ¼ Sec. 15 (10 N., 5 W.) a slope mine has been worked for some years. Here, with the aid of Mr. Andrews, an experienced miner and geologist, the following section was obtained:

1.	Surface and yellow drift clay	5 feet.
2.	Blue gray argillaceous shale	21 feet.
3.	Coal "I"	5 feet 2 in.
4.	Fire-clay	4 feet 3 in.
5.	Sandstone	31 feet.

The deposit of shale above the coal is one of the best I have seen in the State. It is of very fine texture, free from grit and all traces of nodular iron ore. Belonging to the same horizon it is very similar to the seam worked at Brazil into sewer pipe and other products. The fire-clay below the coal is, however, inferior in quality, containing a large percentage of pyrites and other impurities and presenting a shaly or laminated appearance.

A short distance north of Patricksburg, in the S. W. ¼ Sec. 10, are two slope mines where the same shale is exposed to a thickness of 16 to 20 feet. The coal in these mines is fully 5 feet thick, pure non-caking block, equal to the best in this or any other State. Both fuel and clay are here present in almost an inexhaustible quantity. The one thing lacking is a railway switch from one of the three roads touching the county by which these resources can be carried to the points where needed.

The horizon of coal "B," is found from 18 to 25 feet below that of "I," and the vein outcrops in many places north and northeast of Patricksburg. The underclay of this coal is from 3 to 4 feet in thickness, of good quality and suitable for terra cotta, and in some places for potter's wares.

Down the Lick Creek Valley, southwest of Patricksburg, the shale overlying coal "I" comes to the surface in a great many places. A railway switch from Woodside could be easily constructed up this valley to Patricksburg, and so open up the way for developing many of these deposits of shale and underlying coal.

At Woodside, John Andrews has two mines from which the well-known "Lancaster Block" coal is secured. The shale overlying the coal is here about 13 feet thick. The upper eight feet could be utilized but the lower part contains too much bitumen. These mines are located on a switch of the E. & I. Railway. A few years ago Mr. Andrews erected a factory at this point for the purpose of making fire proofing, vitrified drain tile, brick, etc. The machinery with which it was furnished was old-fashioned, and the kilns constructed were patterned after those used in Scotland two centuries ago. As a result it has proven a failure and nothing has been done for a year or more. From $10,000 to $12,000 have been sunk, one-half enough to have fitted it up in good shape with the latest improved machinery. All the essentials of a successful clay industry are present, and a plant constructed and carried on in modern style would doubtless prove remunerative; but Old World methods can not compete successfully with those of the fast striding, onward moving West.

At the air-shaft of an abandoned mine, 100 yards west of the E. & I. Railway at Coal City, and but a short distance from the Clay County line, is an exposure of shale of good quality. The land, N. E. ¼ of S. W. ¼, Sec. 11 (9 N., 6 W.), belongs to Jas. F. Hyatt, who kindly furnished me with the following section:

1.	Surface and yellow clay	7 feet.
2.	Blue argillaceous shale	28 feet.
3.	Coal	4 feet.
4.	Fire clay	3 feet.

On the S. E. of the S. W. ¼ of the same section a bore was put down 94.8 feet through the vein of block coal. Of this distance 47 feet was composed of blue shale and soapstone.

Mr. Hyatt is operating at Coal City one of the largest ordinary brick yards in western Indiana. More than three millions were made in 1895. The clay used is the surface yellow clay, which is here free from lime and other impurities, and makes a strong and lasting brick which find a ready market in many of the towns of the adjoining counties. This clay at the yard lies directly over the shale (No. 2) of the above section. By putting in additional machinery suitable for the making of paving brick, a combination plant could be operated which would doubtless prove a success.

One and three-fourth miles southwest of Freedom, on the land of John McIndoo (N. E. ¼ Sec. 32, Tp. 9 N., R. 4 W.) is a large deposit of pinkish red clay which lies near the surface. The first outcrop visited was by the roadside about one-eighth of a mile north of the I. & V. Railway, where the vein of this clay has been proven by digging to be 6 feet in thickness, and overlain with from 5 to 7 feet of soil and yellow clay. Just across the road, on the land of Israel Light, (S. W. of S. E. of Sec. 29,) the same vein comes to the surface. Further north and west it extends over quite an area, and in places on the lands of A. J. Nelson and Jas. Patterson, it has been stripped and shipped for a number of years to the Encaustic Tile and Terra Cotta Works at Indianapolis, the Encaustic Tile Works at Anderson, Indiana, and to Newark, New Jersey. Probably 800 car loads have been sold, the clay being hauled in wagons 1¼ miles to Farmers Station, where it brought from $1.50 to $2.00 per ton on board the cars.

This is one of the high-grade commercial clays of Indiana, being very fine grained and in most cases free from grit and gravel, tough and exceedingly plastic. Streaks of a whiter color occasionally run through it, which when present in any quantity deteriorate its value for the uses to which it is at present put. That found on the McIndoo land, above noted, contains fewer impurities than at any other exposure visited, and it is more accessible to a railway.

On the land of J. R. Payne, near the center of Sec. 29 (9 N., 4 W.), the same clay outcrops in a ravine. In a well a few rods east of this outcrop the following section was exposed:

1.	Surface and yellow clay	10 feet.
2.	Blue argillaceous shale	14 feet.
3.	Pinkish red plastic clay	? ?

This would tend to prove that the pinkish clay is a decomposed shale, and not a surface deposit, as has been formerly believed. This clay is used by the Encaustic Tile Company to mix with a less refractory clay from Carbon, Ind., in the making of red floor tiling. It is too pure and refractory to use alone, twisting and shrinking out of shape under the influence of great heat. When it becomes more generally known it will probably be put to far more extensive use than at present.

Among the jars of clays in the State Museum, collected by S. S. Gorby, is one filled with very fine white kaolin, and having on the label the name of J. H. Ward, Spencer, Ind. No other data accompanied it, and no such person is known in the vicinity of Spencer. That deposits of kaolin similar in quality to that of Huron, Lawrence County, occur in Owen County, has long been known, yet but little has been done towards developing them.

An outcrop occurs five miles southeast of Spencer, Sec. 12 (9 N., 3 W.), on the land of Mrs. Hopewell, a resident of Bloomington, Ind. A slope shaft was put in a short distance a few years ago, and excellent samples obtained. A visit to the place showed that the opening had been closed by the soil washing down over it. A quantity of the kaolin, stained by iron oxide, was lying near, but no specimens of the better grade were secured. In the Geological Report for 1875, p. 359, Professor Collett mentioned a similar outcrop as occurring in the N. E. ¼ Sec. 7 (9 N., 3 W.), four miles west of the one mentioned above. The kaolin probably underlies the greater portion of township 9 N., R. 3 W., but the thickness and quality of the stratum can only be determined by a more extensive investigation of the known outcrops.

In the vicinity of Gosport are many deposits of the better grades of surface clays. In a ravine on the land of D. W. Buskirk, in the northern limits of the town (N. E. ¼ Sec. 31, Tp. 11 N., R. 3 W.), is an outcrop of yellow clay which by excavation has been shown to be 8 feet in thickness. It is much lighter colored and finer grained than the ordinary surface clays of the surrounding hills, and judging from appearance will make a good dry-pressed front brick. To the west it becomes more silicious and approaches in character a fire clay. The surface clays overlying the outcropping Knobstone shales are suitable for ordinary soft mud brick, and the mouth of the ravine, between the deposit of yellow clay mentioned above and the two railways, presents an attractive location for a combination plant, capable of making both dry-pressed and ordinary brick.

The Knobstone shale, which forms the lowest surface rock visible in Owen County, is exposed in a bold bluff for nearly half a mile just south of the junction of the "Monon" and I. & V. Railways. This exposure is on the lands of Dr. Jno. W. Smith and Maj. A. H. Wampler, in the N. E. ¼ Sec. 31 and the N. W. ¼ Sec. 32 (11 N., 2 W.). This shale is grayish blue in color, free from lime and iron impurities, and with the proper manipulation makes a good article of buff, pressed front brick. Sample brick from a similar material at Martinsville, Ind., made by Boyd, White & Co., of Chicago, are unexcelled in general appearance. The railway facilities at Gosport are excellent, and cheap fuel can be obtained from the mines of Greene and western Owen counties.

GREENE COUNTY

comprises an area of 540 square miles south of the counties of Owen and Clay. It lies in the form of a parallelogram and is divided into almost equal halves by the West Fork of White River, which flows in a southwesterly direction through the county. This stream is joined at Worthington by Eel River from the northwest, and below Bloomfield by Richland Creek from the northeast. Three railroads pass entirely through the county and furnish excellent facilities of transportation for its resources.

The Conglomerate Sandstone, the western border of which is a most unerring landmark of the eastern horizon of the coal measures proper, forms the surface rock in fully three-fourths of the county. For this reason the best beds of shale and clay, as well as of coal, are found west of the main line of the I. & V. Railway, which follows approximately the western border of the conglomerate. In the eastern half of the county the sub-conglomerate coal "A" outcrops and is mined in a number of localities, but can nowhere be relied upon to supply more than a local demand. Beds of shale suitable for commercial purposes are rarely found above coal "A," but the fire-clay beneath it is oftentimes of excellent quality.

On a hillside just west of Owensboro, and a short distance north of the Bedford & Bloomfield Railway, in the N. E. ¼ Sec. 28, Tp. 6 N., R. 3 W., is an outcrop of fire-clay of excellent quality for the making of stoneware. It was long used for this purpose at the Reynolds pottery, which was located three miles southwest of the deposit. The clay stratum is between 3 and 4 feet in thickness and can be reached by easy stripping.

A bed of similar potter's clay is located on the land of L. J. Faucett (N. E. ¼ of S. E. ¼ Sec. 31, Tp. 7 N., R. 4 W.), one-half mile northwest of Mineral City and but one-eighth of a mile from a switch of the B. & B. Railway. It is exposed by the side of a small stream, is 5 feet in thickness and covered with a layer of soil 4 feet in depth. This clay is grayish-white in color, and contains free silica in sufficient quantities to prevent air cracking while cooling. It has been tested in the pottery at Worthington and found in every way suitable for the making of the better grades of stoneware.

One-half mile south occurs an outcrop of shale in the side of a bluff of Plummer's Creek. The strata exposed at this point are as follows:

1.	Soil and yellow clay	10 feet.
2.	Gray arenaceous shale	8 feet.
3.	Sandstone	6 feet.
4.	Soft blue argillaceous shale	8 feet.

The two shales are suitable either for pressed front brick or vitrified products.

The above clay deposits were all that my limited time allowed me to visit east of White River. Kaolin, similar to that found in Lawrence and Martin counties, is reported by Mr. E. F. Cox, the County Surveyor, to outcrop on the land of Jas. Sullivan in Beech Creek Township (S. E. ¼ of N. E. ¼, Sec. 10, Tp. 7 N., R. 3 W.), and on that of W. R. Arthur, near Newark. The extent and thickness of these beds have not, as yet, been investigated.

At Switz City, the junction of the I. & V. and B. & B. railways, there is found, about three feet below the surface, a thick stratum of tough, blue drift clay, which makes a most excellent drain tile. A factory for their production has been in operation for 5 years and the annual output is constantly increasing.

One-half mile northwest of the town, on land owned by J. B. Spencer (Sec. 15, Tp. 7 N., R. 6 W.), a vein of "fire clay" 4½ feet in thickness underlies a thin stratum of coal. The clay is free from visible impurities, and while not of high refractory grade, it will make excellent sewer pipe or terra cotta.

Linton, situated near the western border of Greene County, is one of the more important mining centers of Indiana. The coal veins found near there range from 4 to 6 feet in workable thickness, and the output ranks in quality among the best bituminous. As good deposits doubtless occur farther north in Wright and Smith townships, but a lack of means of transportation has, up to the present, prevented their development. The shales overlying the coal seams in the vicinity of Linton are, for the most part, too far beneath the surface to allow them to be obtained by stripping. As a consequence no use has heretofore been made of them.

The following connected section was obtained at the shaft of the South Linton Coal Company (S. W. ¼ Sec. 23, Tp. 7 N., R. 7 W.) and at shaft No. 2 of the Island Coal Company, one-half mile farther west. It may be taken as representing the average sequence of the strata through the worked seams of coal in the region about Linton.

1.	Soil and yellow drift clay	10 feet.
2.	Grayish, arenaceous shale	12 feet.
3.	Dark bituminous shale (black slate)	9 feet.
4.	Coal (top vein)	6 in. to 1 ft. 4 in.
5.	Fire clay	3 feet 4 in.
6.	Sandstone, gray, compact	18 feet.
7.	Light gray argillaceous shale	7 to 10 feet.
8.	Dark blue argillaceous shale	17 to 20 feet.
9.	Coal	5 to 6 feet.
10.	Hard fire clay, soon merging into sandstone.	? ?

Of these No. 2 is too silicious for use. Fire clay, No. 5, is of good quality, but the seam of coal above is too thin for working in connection with it. The clay will probably, therefore, never be utilized.

The shales (Nos. 7 and 8) comprise 24 to 30 feet of material, in every way suitable for manufacturing purposes. No. 7 is a soft and unctuous fine grained deposit resembling many of the under-clays in general appearance. It is free from sulphur and iron concretions and is the more valuable of the two. Having above it a good sandstone roof, and below it a bottom of shale, it could be readily and easily mined if occasion should arise to take it out by itself.

No. 8 is darker, harder, and more compact. It forms the roof of the worked seam of coal and, where exposed to air in the entries, it has, like all shales, a tendency to crumble and fall. Much of it, therefore, must, in the older mines, be handled, and either stored in worked out areas or raised and thrown on the dump. This being the case, and the fuel and railway facilities both being present, a factory at Linton for making these shales into vitrified products would, without doubt, prove a paying investment. An analysis of a specimen of No. 8 shale, taken from the dump at the shaft No. 1 of the Island Coal Company, showed the following composition:

Clay base and sand	86.40 per cent.*
Fluxes	13.11 per cent.

This shows a close approximation to the standard average composition of shales used for vitrified products and proves the *chemical fitness* of this shale for such products.

The fire clay (No. 10) below the worked seam of coal is, in most places, very thin, and soon merges into a hard and compact sandrock. At the South Linton Mine the coal lies directly upon the sandstone which is so hard that the miners have much difficulty in sinking their sumps, and the holes for the placing of the roof props.

West and northwest of Worthington are many outcrops of shales and underclays. A pottery has been operated on a small scale in that town for more than 25 years. The clay has been mostly obtained from the land of Mark Hays, three miles west of Worthington. The stratum lies beneath an outcrop of coal "B," is but 2½ feet in thickness and requires much washing to remove the impurities. A better quality of potter's clay has recently been tested and will be hereafter used. It is from the land of H. S. Shouse, (Sec. 12, Tp. 8 N., R. 6 W.) where it occurs in quantity.

Northwest of Worthington a vein of coal from 2 to 2½ feet in thickness has been passed through in digging many wells. Below this is a vein of fire clay 3 to 4½ feet in thickness and suitable for terra cotta and

* Lyons, chemist. For complete analysis see table at end of chapter.

kindred uses. In most places this merges into a fine grained shaly sandstone. Such a deposit of fire clay was found on the land of Chas. Dayhoff (S. E. ¼ Sec. 15,) and on that of Mr. Darnell (S. W. ¼ Sec. 10,) both in Tp. 8 N., R. 6 W.

At the time of my visit a seam of coal on the land of Mrs. S. J. Fuller, (S. W. ¼ of N. W. ¼ Sec. 12, Tp. 7 N., R. 6 W.,) was being mined by stripping. The following section had been exposed:

1.	Soil and surface clay	4 feet.
2.	Drab, argillaceous shale	4 feet.
3.	Coal	2 feet, 2 in.
4.	Fire clay	??

Nos. 2 and 4 are both free from grit and above the average in quality. The location, however, is too distant from transportation to allow them to be of present value.

Among the clays collected by the former Geologist, S. S. Gorby, is one bearing the label of Sol. Davis, Worthington, Indiana. No notes accompany it, and letters written to the address on the label have received no response. It is a gray underclay of good quality, as evinced by the following record of its analysis made by Dr. J. N. Hurty and given on the label:

Silica (total)	63.25	
Alumina	24.81	
Clay base and sand		88.06
Magnesia	1.01	
Lime	.48	
Ferric oxide	3.04	
Fluxes		4.53
*Moisture and volatile		7.33

This proves its fitness for either terra cotta or sewer pipe.

The above comprise the principal clays of note in those parts of Greene County which I was enabled to visit. That many others occur, especially in the northwestern part of the county, there is no doubt. These will in time be investigated and brought to public attention. Meanwhile, those mentioned are sufficient in quantity and quality to merit the investment of capital for their development; and where fuel is easy of access and railway facilities at hand, no fears may be felt as to the success of such investment.

*This probably includes some potash and soda.

SULLIVAN COUNTY.

On the western border of the State, just south of Vigo and west of Clay and Greene counties, is Sullivan, a county whose mining interests are rapidly becoming of great importance.

It comprises 443 square miles, all of which are underlain with the Coal Measure rocks. The Wabash River forms the western boundary of the county and receives from the east Turman's, Turtle and Busseron creeks, which branch and ramify into all portions of its area. The eastern part of the county is broken, and the soil, except the low ground near streams, is comparatively poor. The western two-thirds is for the most part level prairie, or river terrace, and possesses a much richer soil.

Two coal seams of workable thickness are mined at many points in the eastern half of the county. The main line of the Evansville & Terre Haute Railway passes north and south through the county, and marks, approximately, the western limit of mining operations, as west of that railway the thicker veins of coal are found at too great a depth to allow of profitable working. The principal exposures of carboniferous shales and fire clays are, therefore, east and northeast of Sullivan, the county seat, which is located in almost the geographical center of the county.

Near the foot of the bluff bordering the bottoms of Busseron Creek on the land of Lewis Eaton (N. ½ of S. E. ¼ Sec. 36, Tp. 8 N., R. 9 W.), a shaft has been recently put down through the top vein of coal, which at this point is about 25 feet below the surface. The mine was not being worked at the time of my visit, but the following section was secured of the strata exposed in the shaft:

1.	Soil and drift clay	6 feet.
2.	Blue, argillaceous shale	17 feet.
3.	Dark, bituminous shale	2 feet.
4.	Coal	3 feet 2 in.
5.	Fire clay	?

Shale No. 2 is a hard, compact, fine grained material which weathers freely on the dump into a plastic mass, valuable for many products. No samples of the fire clay underlying the coal were obtainable, but it is doubtless similiar to that underlying the same coal farther east. This mine is one-fourth of a mile south of the I. & I. S. Railway and one and one-half miles east of the E. & T. H. Railroad.

The mine of Watson, Little & Co. is the third one operated east of Sullivan and is located by the side of the main line of the I. & I. S. Railway. Both veins of coal have here been worked, but the upper one has been recently abandoned, as the output from it, when allowed to stand any length of time, air slacks too rapidly to be of value. If used immediately after being mined, it is, however, an excellent fuel. The upper vein is 49 feet below the surface and the lower one 93. An air shaft was being sunk at the time of my visit and the material from it gave excellent opportunities for examining the character of the strata above the first vein. Of them the following section was obtained:

1.	Surface soil and clay	8 feet.
2.	Gray argillaceous shale	23 feet.
3.	Blue argillaceous shale containing remains of fossil plants	16 feet.
4.	Bituminous shale, fissile	2 feet.
5.	Coal	4 feet.
6.	Fire clay—dark plastic	6 feet.

Of these, all of shale No. 2 and the upper half of No. 3, comprising 31 feet in vertical thickness, are suitable in the highest degree for vitrified brick and similar wares. The fire clay will make a good grade of terra cotta, and may be mixed with the overlying shales for vitrified products, but it evidently contains too high a percentage of the fluxes for refractory purposes. The three things necessary for the production of clay products, viz.: raw material, fuel and transportation, are here present in one spot. Where so combined the finished products may be made at prices that will defy competition. Moreover, if a plant should be located here, the top vein of coal would supply an excellent fuel, as it could be mined only as needed, thus preventing the air-slacking for which it is now condemned.

At Farnsworth, one-half mile east (N. W. ¼ of N. E. ¼ Sec. 32, Tp. 8 N., R 8 W), is located the large mine of Hancock and Conklin. This mine was opened in 1880, the energetic proprietors digging the shaft with their own hands. The first year or two only the top vein of coal was worked, but here, as elsewhere, its quality is inferior to that of the lower vein, and only the latter is now mined. The shaft is located on the I. & I. S. R. R., and a section through it to the bottom of coal "L" is as follows:

1.	Soil and drift clay	12 feet.
2.	Gray arenaceous shale	17 feet.
3.	Blue argillaceous shale	8 feet.
4.	Coal	3 feet 4 in.
5.	Fire clay	8 feet.
6.	Bastard grayish limestone	2 feet 6 in.
7.	Blue argillaceous shale with occasional nodules of iron carbonate	18 feet.
8.	Bituminous shale, fissile	3 feet.
9.	Coal	5 feet 6 in.
10.	Fire clay soon merging into gray, sandy shale	??

The top shale, No. 2, contains more silica than that at Watson, Little & Co.'s mine, and its quality for making vitrified material is, therefore, somewhat impaired. On the other hand shale No. 7 is of better quality than there, being a fine grained, gritless material. All of fire clay No. 5 and 15 feet of No. 7 shale can be utilized for paving brick or sewer pipe.

Two miles farther east, on the land of Robert Pigg (N. E. ¼ of N. E. ¼ Sec. 34, Tp. 8 N., R 8 W.), a mine has recently been opened to supply the local trade with coal. The shaft, sunk only through the upper vein, disclosed the following strata:

1.	Soil and yellow clay	4 feet.
2.	Shaley "pepper and salt" sandstone	8 feet.
3.	Blue argillaceous shale	16 feet.
4.	Coal	3 feet 4 in.
5.	Fire clay	??

Samples of the shale and fire clay show them to be in every way suitable for vitrified products. This mine is seven miles east of Sullivan and three-fourths of a mile north of the I. & I. S. R. R.

The "Jumbo" mine of the Jackson Hill Coal Company is located in the S. ½ Sec. 10, Tp. 8 N., R. 8 W. It is probably the largest mine operated in the county. The lower seam of coal is worked, the upper one not being present where the shaft was sunk. The only commercial clay at the mine is an unctuous blue shale, remarkably free from grit and fine in texture, which overlies the coal for a thickness of 14 feet. Above it is 8 feet of sandstone and 5 feet of surface soil

The coal, here 5½ feet thick, rests upon a blue shale, instead of a fire clay. The same conditions exist at the "Star City" mine, two miles northwest of the "Jumbo."

In general it may be stated of this region that wherever the upper seam of coal exists it is overtopped with 15 or more feet of shale and underlain with from 6 to 9 feet of fire clay, both of which are suitable for vitrified products. Between the two veins of coal, and overlying the dark bituminous shale which forms the roof of the lower vein, is also from 15 to 25 feet of an excellent argillaceous shale.

For a number of years a mine was worked at Sullivan, the shaft being located about 200 yards north of the E. & T. H. station Owing to litigation it was abandoned about 1891, and no one could be found who was able to give information concerning the strata passed through above the coal. The vein worked was about 250 feet below the surface. From the clay underlying it a Mr. Pollock made, for a time, vitrified drain tile and paving blocks for sidewalks. His plant was located near the coal shaft, and was abandoned soon after work ceased at the mine. The machinery, engine, pug mill, etc., as well as one down-draft kiln and 200 feet of shed room, still remain in position.

A short distance north of Carlisle, by the side of the E. T. H. Railway, Mr. J. P. Walls is at the present time manufacturing, on a small scale, fire and ornamental brick from the vein of fire-clay 8 feet thick which underlies the top vein of coal. He informs me that this clay withstands great heat with but little shrinkage, and the products do not crack in drying or burning. The top coal at that point is 3 feet thick and gives good satisfaction as a fuel in burning ordinary brick, of which he makes large numbers.

But one deposit of potters clay is known to occur in Sullivan County, though many of the more plastic underclays could probably be used for that purpose. The one mentioned is found in the S. W. ¼ Sec. 9, Tp. 6 N., R. 8 W. It is a light gray clay of great purity, and was for a long time used at Pleasantville in making a better grade of stoneware. The stratum of clay has an average thickness of about 3 feet and is readily accessible.

From a lack of time I was not enabled to visit the northeastern townships of Sullivan County, where it is very probable that outcrops of shales and underclays of even greater value than those mentioned occur. I can only hope that what I have written will call the attention of the owners of coal lands and the citizens of the county generally to these hitherto wholly neglected resources in their midst, and that steps will soon be taken which will eventually lead to the erection of factories for their utilization.

KNOX COUNTY

comprises one of the most fertile sections of southwestern Indiana. The Wabash River forms its western boundary and White River its eastern and southern. The broad valleys of these streams form a large portion of the surface of the county and greatly increase the average richness of its soils. Five hundred and forty square miles are comprised within its bounds. The upper or barren coal measures form the surface rocks of the greater part of this area. The lower or productive measures underlie the whole county, but at such a depth as to prevent the remunerative mining of coal, except at a few points along the eastern border, where the principal veins of these measures outcrop in the bluffs of White River.

The upper or barren measures are made up for the most part of alternating strata of sandstone and shales. At intervals are thin beds of "rash" coals of no economic value. The total thickness of these deposits is more than 300 feet, and above them lie, in most parts of the county, from 50 to 75 feet of drift, alluvium or loess, which hide the more compact rock strata from view. For example, at Vincennes, the county seat, the first sandstone found in a test bore put down in the City Park was at a depth of 71 feet, and the first vein of coal of workable thickness at a depth of 383 feet.

With so great a covering of surface deposits it is difficult to locate the underlying shales and fire-clays. At Vincennes two shafts have been sunk and the coal mined. One of these has been recently abandoned. The other, the Prospect Hill Mine, is being worked for the local trade. The shaft was sunk in a comparatively low place near the Sugar Loaf Mound, one and one-half miles southeast of the City Hall. The worked vein of coal, probably "M," is found here at a depth of 355 feet. It is 4 feet thick and has above it a stratum of fine grained, gray arenaceous shale, 42 feet in thickness. This forms an excellent roof, being massive instead of in laminæ, and when blasted breaking with a conchoidal fracture. An analysis of this shale by Prof. Noyes shows its composition to be as follows:*

Clay base and sand	84.84
Fluxes	12.94

Comparing this with the standard composition of clays suitable for vitrified products (see p. 54), we find it varying but slightly, and that towards a greater purity. Future tests in the kiln will most probably prove what the chemical composition intimates, and show conclusively the fitness of this shale for paving brick and kindred products.

The under clay beneath the coal at the Prospect Hill Mine has been pierced to a depth of ten feet without reaching the bottom. It is a dark gray plastic material, of exceeding fine texture, and with an occasional trace of stigmaria. An analysis of a sample of clay from the same stratum taken from the mine of the Vincennes Coal Co., one-half mile northeast, was made a few years ago by Dr. J. N. Hurty. Mr. Frank Clarke, the present operator of the Prospect Hill Mine, has kindly procured me a copy of this analysis as follows:

Silica (total)	65.315		
Alumina	28.473		
Clay base and sand			93.788
Lime		.179	
Magnesia		2.741	
Ferric oxide		3.120	
Fluxes			6.040
Moisture			.170

"This clay burns a yellowish white and will make excellent fire brick."

J. N. Hurty,

Analyst.

It can also be made into terra cotta, sewer pipe, and fire-proofing for walls and chimneys. Two feet of the clay has to be blasted out in all the entries for height. Most of this is stored in worked out areas, but

* For complete analysis, see table at end of chapter.

hundreds of tons of it and the shale above the coal are raised to the dump, where they soon weather into a fine plastic mass.

In the vicinity of Edwardsport, in the northeastern part of Knox County, three seams of workable coal outcrop. These were designated as "K," "L" and "M," by Prof. John Collett, who studied them in 1873. One and one-fourth miles north of Edwardsport (N. E. ¼, Sec. 36, Tp. 5 N., R. 8 W.), a slope shaft was put into a hill in 1895. This is known as the Hoffman Mine. Test bores put down in the side of the hill above the shaft show the presence of the following strata:

1.	Soil and drift clay	12 feet
2.	Blue arenaceous shale	10 feet
3.	Coal "L"	3 feet 2 in.
4.	Fire clay	3 feet 4 in.
5.	Blue argillaceous shale	39 feet
6.	Dark bituminous shale (black slate)	3 feet
7.	Coal "K"	5 feet 3 in.
8.	Fire clay	2 feet

The fire clay No. 4 is very similar in appearance to that found at Vincennes, and can be used for the same purposes. The blue shale No. 5 has the fine texture and unctuous feel characteristic of the better grades of materials suitable for hollow brick, pre sed front and paving brick, and kindred products.

Nearer town, in the S. E. ¼ Sec. 35, the fire clay at the level of coal "L," was found to be 9 feet thick. Just south of the I. & V. Railway station an exposure of shale suitable for pressed front brick lies alongside the railroad track. It is 6 to 8 feet in thickness and overlies coal "L," which is here exposed to a depth of about 3 feet.

At the Keith mine, three-fourths of a mile south of Edwardsport (N. E. ¼ Sec. 4, Tp. 4 N., R. 8 W.), the fire clay beneath coal "K," which is here worked, is about 4 feet thick, but is much inferior in quality to that found below "L," higher up. It is more silicious than the latter, and contains some pyrites, and many stigmaria and other plant remains. A short distance below this (S. E. ¼ Sec. 4) coal "K" outcrops at low water mark in the bed of White River. At this point it is overlain with a black calcareous shale, above which is a dark-colored limestone; the two together aggregating about 8 feet in thickness and containing numerous fossils, among which are sections of some very large crinoid stems and spines.

In general, it may be stated of the area in the vicinity of both Edwardsport and Bicknell, that the fire clay beneath the top vein of coal ("L,") and the blue shale overlying the bottom vein ("K,") are both of excellent grade for manufacturing. At Bicknell the top vein lies 42 feet below the surface, and the lower vein 92. Both are worked, and the fire clay and shale above mentioned aggregate about 14 feet in vertical thickness.

The location of a large clay industry at either the Prospect Hi Mine near Vincennes, or the Hoffman Mine north of Edwardsport, can not but prove a paying procedure. At both places raw material in abundance and of excellent quality for many products, is found. At both, fuel for burning this material is plentiful. The Hoffman Mine has a railway switch already completed. One can easily be constructed to the Vincennes mine, and the latter being placed in connection with the four railways entering that city, will then have the better transportation facilities. As I have before stated, where raw material, fuel and transportation are found in one spot, clay products can be produced at prices that will defy competition.

DAVIESS COUNTY.

Lying south of Greene and west of Martin County is Daviess, one of the better agricultural counties of southwestern Indiana. It comprises an area of 424 square miles, the larger part of which is covered with the rocks of the coal measures. The West Fork of White River forms the western boundary of the county and the East Fork the southern boundary, the two uniting at the southwestern corner. The northeastern part of the county is quite broken with the characteristic hills and ridges of the conglomerate sandstone which here forms the surface rock. The western and southern parts are more level, with better farming lands especially suited to the raising of wheat which is the staple crop.

Washington, the county seat, secured in 1891 the shops of the Baltimore & Ohio Southwestern Railway. Since that date it has almost doubled in size, possessing at the present a population of about 8,500. Within its immediate vicinity are the principal coal mines of the county, as well as the larger deposits of commercial clays which lie close enough to railways to admit of profitable working. Many shafts have been sunk and bores put down east and south of Washington. These prove the presence of shale and fire clay deposits in abundance, though in but few places do they come so near the surface as to admit being worked by stripping.

One of these is two miles north of the city on the land of Mrs. R. Shepherd (S. E. ¼ Sec. 14, Tp. 3 N., R. 7 W.), where a blue argillaceous shale outcrops along the banks of a small stream. The shale is exposed to a depth of 10 feet, and is overlain with 5 feet of homogeneous yellow clay of excellent quality. The two can be mixed and be made into dry pressed brick, paving brick and many other products.

One-half mile south of the depot of the B. & O. S. W. R. R., at the point where the bridge on the Petersburg road crosses the cut of an old railway switch, is an outcrop of "soapstone," or soft unctuous shale 20 feet thick. The switch could be easily replaced and the deposit utilized. The clay is of the better quality, and suitable for many purposes.

At Cable & Kaufmann's No. 4 mine (S. W. ¼ Sec. 3, Tp. 2 N., R. 7 W.) the seam of coal mined is so thin as to necessitate the removal of several feet of material either above or below, in order to make height for mules and cars. The fire clay beneath the coal is one of the best underclays for terra cotta and similar products that has come to my notice. It is of very fine texture, and free from the impurities that many such clays contain. Thousands of tons of it are raised each year, and up to the present the dump pile has been its landing place. The vein is said to be 7 feet thick, of which the upper 2½ feet is taken out. Above the coal is a soft, gray, argillaceous shale, which can be mixed to good advantage with the fire clay, and the two made into vitrified products.

A few rods south of this mine a bore was recently put down 800 feet in search of coal. At this depth a strong flow of mineral water was obtained which has continued unabated. This water has proven beneficial for many diseases, and at the time of my investigation large quantities were being carried away daily in jugs and kegs by the people of Washington and vicinity. The owners of the well had had an analysis of the water made by Werner & Simonson, of Cincinnati, which showed the presence of the following mineral salts in the quantities given:

	Grains per Gallon.
Calcium sulphate—Gypsum salts ($CaSO_4$)	75.712
Calcium carbonate—Salts of lime ($CaCO_3$)	9.256
Magnesium chloride—Salts of magnesia ($MgCl_2$)	88.480
Magnesium bromide—Salts of magnesia ($MgBr_2$)	.605
Potassium sulphate—Potash salts (K_2SO_4)	7.168
Sodium sulphate—Glauber's salts (Na_2SO_4)	488.088
Sodium chloride—Common salt (NaCl)	1014.336

A record of the bore put down at the well as kept by Cable & Kauffman shows the presence of the following strata above the second vein of coal:

1.	Soil and drift	13 feet.
2.	Gray arenaceous shale	16 feet.
3.	Coal	3 feet 6 in.
4.	Fire clay	7 feet 6 in.
5.	Gray argillaceous shale	12 feet.
6.	Blue argillaceous shale	13 feet.
7.	Gray sandy shale	22 feet.
8.	Blue argillaceous shale	36 feet.
9.	Dark bituminous shale	6 feet.
10.	Coal	1 foot 6 in.
11.	Fire clay	11 feet 6 in.

Of these Nos. 4, 5, 6, 8 and 11 are clays suitable for manufacturing purposes. These aggregate 80 feet out of a total of 146—and, taken in connection with the coal and the switch already in place, form a combination hard to excel for a great clay manufacturing site.

At the old Wilson shafts, Nos. 1 and 2, just east of the corporate limits of Washington, coal "L", which has been largely worked out, is underlain with 7 feet of fire-clay. Beneath the latter is a gray sandstone 5 feet in thickness. This overlies a blue argillaceous shale, which, according to bores made by Thomas Wilson, one of the former owners of the mine, is 37 feet thick. Mr. Wilson, who is an experienced observer, states that the shale closely resembles that used at Clinton for the making of vitrified street brick.

Numerous bores have been put down between Washington and the town of Montgomery, six miles east. These all prove the presence of the carboniferous shales in large quantities. At the mine of the Daviess County Coal Company, just west of Montgomery, large quantities of the fire clay underlying the worked seam of coal have to be removed. Although of excellent quality it is not utilized but is relegated with other refuse to the dump pile. The large expense necessary to mine and raise it is thus totally lost.

Three-fourths of a mile southwest of Montgomery (S. E. ¼ Sec. 27, Tp. 3 N., R. 6 W.), near the residence of Mike O'Heffernan, an outcrop of potter's clay 3 feet thick occurs by the roadside. It has been tested and proved of good quality for the making of ordinary stoneware.

Some excitement has been created in the vicinity of Washington by the statement that gold and platinum had been found in paying quantities on the farm of Cross Bros (N. E. ¼ Sec. 17, Tp. 2 N., R. 6 W.). A visit to the place showed that a shaft had been sunk to a depth of 14 feet, disclosing the following strata:

1.	Soil and surface clay	4 feet.
2.	Dove-colored argillaceous shale	6 feet.
3.	Dark bituminous shale	4 feet.

Shale No 2 is a soft "soapstone," divided into thin layers or laminæ, between which is an incrustation of oxide of iron. This was pointed out to me as the gold-bearing material, and the statement was made by Mr. F. M. Cross that it had been assayed and found to contain gold to the amount of $36 to the ton. It is needless to say that such a statement is absurd. The shale will make a fair quality of vitrified brick or sewer pipe, but all the gold or platinum contained in forty acres of it would not pay one-eighth of the amount spent in sinking the shaft.

The yellow surface clay found in the vicinity of Washington is in quality much above the average of the surface drift clays of the counties to the north. It is almost wholly free from lime or other pebbles, is very fine grained, and the deposits, averaging 15 to 18 feet in thickness, are of uniform character throughout. It can be made into a fine, dry-pressed front brick. The ordinary soft mud brick made from it are harder, tougher and of better quality generally than those made of the drift clays to the north. Mixed with fire clay or shale in the ratio of 1 part to 3, this clay will add to their value for making many products.

Within two years more than three millions of vitrified brick and block from Evansville, Ind., and Athens, O., have been shipped to Washington and put down in the streets. These have cost from $10 to $14 per thousand. The raw material for making them and the fuel for burning them was to be found in abundance within two miles or less of the spot where they were laid. The sum sent out of the county in payment for this paving material would have paid for a good plant for manufacturing it, which would have furnished labor for many hands.

The B. & O. S. W. and the E. & I. railways, or their switches, pass through the leading deposits mentioned above, and connect the city of Washington with numerous towns in Illinois and Indiana where paving brick and other clay products will in the future be used in quantity. The people of Washington should see to it that a factory is soon erected for utilizing on a large scale some of the excellent clay materials with which the city is surrounded.

MARTIN COUNTY

comprises an area of 340 square miles of territory lying south of Greene and east of Daviess County. Its surface is very rugged and broken, not more than one-third being capable of cultivation. The East Fork of White River enters the county near the middle of its eastern border, and flows in many meandering curves to near the southwestern corner, where it turns to the west and forms a small portion of the southern boundary. This stream and its main tributaries from the north and south have been the chief agents in carving the surface rocks into fantastic shapes and ploughing those deep gulches and valleys which are so prominent a part of the scenery of the county.

The Coal Measure rocks form but a small portion of the surface, and that only on the tops of the higher and more prominent hills. The formation prevailing over the greater part is the millstone grit, or conglomerate sandstone. This is most commonly an even grained sandstone of a reddish brown color, the lower part, only in a few places, containing the agglutinated quartzose and other pebbles to which the name "conglomerate" rightfully belongs.

The sub-conglomerate coal "A" is mined at a number of places in the county and outcrops at many more. The under-clay accompanying this seam of coal is a light gray plastic material. Its refractory qualities are not of the best, but are sufficient for potters' use, and large quantities of stoneware have in the past been made from it at both Loogootee and Shoals.

At the former place a pottery was started in 1842 by Upton Stuckey, and continued in operation until 1892. The clay used was obtained from beneath coal "A" on land now owned by Mrs. Charlotta Wood, two miles north of Loogootee. The stratum of clay is here three feet thick, and is obtained by easy stripping. The same clay outcrops in one or two other places on the same land, but the stripping necessary to get at it is much more extensive. According to Mr. Stucky it makes a "nice blue stoneware which does not check in drying." Two other potteries have in the past drawn their supplies of clay from this same deposit.

At Shoals a pottery was established about 1870, and continued in operation until 1892, when it was merged into the Indiana Clay and Specialty Works, which manufactures stoneware, vases, etc., on a more extensive scale. The clay used is of two kinds, and is secured at Sampson's Hill, two miles southeast of Shoals, in the W. ½ Sec. 6 (2 N., 3 W.), where the following section was obtained from the top of the hill through the under clay of the coal:

1. Hard, gray-pinkish sandstone........................1 foot 6 in.
2. Soft dark blue clay.................................6 feet.
3. Coal..1 foot.
4. Light gray potter's clay............................4 feet 6 in.

Of these Nos. 2 and 4 are combined in varying proportions according to the kind of wares required. Both are comparatively free from impurities, and contain silica in the proper proportions to prevent air-cracking while drying and cooling.

Kaolin, of the same nature as occurs in Lawrence County, outcrops at a number of places in the eastern half of Martin County, and in a few instances the beds have been worked on a small scale, though not sufficiently to determine their maximum thickness, or to develop the better portions of the deposits. On the south side of White River in the N. W. ¼ Sec. 27 (3 N., 4 W.), two and one-half miles west of Shoals, and one-half mile from the B. & O. S W. Railway, Messrs. Johnson and Chenoworth have put a slope or drift shaft 40 feet into a bed of this clay. The kaolin here is 4½ to 5 feet in thickness, but is not uniform in character, three or four varieties being mixed and inter-stratified in irregular layers. Of these the uppermost is a hard, semi-transparent, milky colored clay; the next lower a soft chalky white to cream colored; the third layer a hard dark amber brown to black, containing much iron oxide, and the fourth or bottom layer a dirty yellowish brown clay of much hardness. The shaft was put in more for prospecting purposes than anything else, and but little of the kaolin has as yet been used. A bore put down on the opposite side of the ridge proved the presence of this kaolin stratum at a depth of 40 feet.

The following are some of the points south of White River in Martin County, at which the kaolin is known to outcrop:

1. Land of Dr. Thomas Ritter, near Willow Valley (N. E. ¼ Sec. 15, 3 N., 3 W.)
2. Land of Dr. Thomas Ritter, near Willow Valley (S. W. ¼ Sec. 14, 3 N., 3 W.)
3. Land of A. W. Stewart, near Pleasant Valley (S. E. of S. E. ¼ Sec. 5, 2 N., 3 W.)
4. Land of ——— ———, near Pleasant Valley (S. W. ¼ Sec. 6, 2 N., 3 W.)

North of White River the kaolin outcrops in a number of places, but two of which I had time to visit. One of these was near the base of the north slope of the hill on which the town of Dover Hill is located. Here on the land of James Yarnell (N. E. ¼, Sec. 1, Tp. 3 N., R. 4 W.), a slope shaft about 50 feet long, and constructed in a crude manner, was put in a few years ago to determine the thickness and quality of the stratum.

Above the kaolin is a soft pinkish sandrock, which crumbles readily when exposed to air. The props supporting this roof had in places decayed away and allowed the crumbling sandstone to fall down and cover the entry to the depth of several feet, so that much difficulty was experienced in getting into the shaft. Once in, the kaolin stratum was found to be between 5 and 6 feet in thickness. This, for the most part, was an amorphous pinkish brown material, made up of small granular masses. The color was evidently due to its being impregnated with the oxide of iron by the leaching of the surface waters through the overlying sandstone. In the upper part of the stratum were many nodular masses three inches in diameter or less, and exteriorly somewhat resembling geodes in appearance. These were easily broken by the hands, the interior being a soft, pearly white, opal-like mass of pure kaolin. When exposed to the air this loses its transparent properties, and hardens in a few weeks into a flint-like body. At intervals in the stratum of kaolin are found large irregular masses of hard gray limestone containing many fragments of crinoid stems and other small fossils. These have been supposed to be pieces of the stratum of limestone which has been dissolved out of the space now occupied by the kaolin. At the base of the stratum of the latter is usually found numerous rough lamellar masses of iron oxide (limonite) averaging about 6 inches in thickness. These rest upon a dark soapstone or shale, the depth of which could not be determined. A careful examination of the surroundings leads me to believe that the stratum of kaolin will thicken somewhat, and become much purer in quality back farther under the hill. The same stratum outcrops again on the south side of the hill or ridge upon which Dover Hill is situated, and undoubtedly underlies the whole ridge at a depth of 125 to 140 feet. The greater part of this tract of land belongs to Dr. A. W. Porter, of Loogootee, who is considering the feasibility of putting in a slope shaft on the northeast side of the ridge, and working the full thickness of the kaolin.

Three-fourths of a mile south of the Indian Springs Hotel, on land belonging to Robt. Kregg, Silverville, Indiana, in the N. W. ¼ Sec. 20 (4 N., 3 W.), is a large deposit of kaolin which was worked for some time, but is now abandoned. A horizontal shaft enters the side of a large hill, and on entering it the same soft, shelly, pinkish sandstone is seen above the deposit as was noticed at Dover Hill, seven miles to the southwest. Several tons of the pinkish brown variety of the clay were beneath a shed to which a tramway from the mine was constructed. Numerous pieces of the accompanying lamellar iron ore were scattered about the mouth of the shaft, but none of the intermingled limestone was noticeable. The same underlying shale was present as at Dover Hill. In the side entries, 100 to 150 feet back from the entrance, the upper half of the vein of kaolin, here 4½ feet thick, was pure white, and almost equal in quality to the best of that found at Huron, Lawrence County. No one was present about the mine, and I could not ascertain what disposition had been made of that taken out, nor why the mine had been abandoned.

This stratum of kaolin probably underlies the greater part of the eastern half of Martin County, at the lower horizon of the conglomerate sandstone; but it will be found to vary much in thickness and quality. Northward it has been found to occur, as already mentioned, at isolated points in Greene and Owen counties.

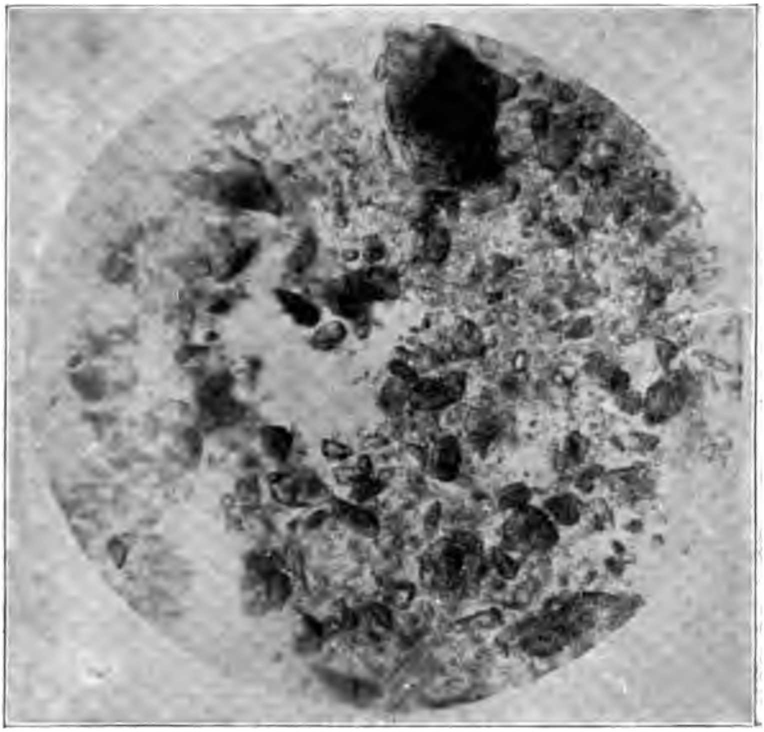
LAWRENCE COUNTY KAOLIN.

This kaolin being the purest form of clay found in Indiana, if not in the United States, an examination was made of the beds of it which have been most extensively worked at Huron, Lawrence County. These are at present owned by Dr. J. Gardner, of Bedford. Although outside of the territory covered by this report, the following facts are here given concerning the Huron deposits, as they will better enable the owners of the kaolin in Martin, Greene and Owen counties to judge of the value of the clay and the uses to which it may be put.

These deposits were first brought to public notice by the State Geologist, E. T. Cox, in the Report for 1874. Locally the outcropping kaolin had been previously known as mineral tallow, and the locality as Anderson's "taller bank." Some workmen in the summer of 1874, while digging out the underlying iron ore for the blast furnace at Shoals, laid bare the full thickness of the stratum of kaolin, and the attention of Mr. Cox was called to it. Dr. Gardner became interested and purchased the land, and extensive tests and analyses were made which proved the great purity and value of the clay. For some years it was mined and sold to Tempest, Brockman & Co., of Cincinnati, who used it as one of the principal constituents in the making of a white porcelain ware of excellent grade. Later the land was sold to the Pennsylvania Salt Co., of Philadelphia. This company for ten years mined annually an average of 2,000 tons of the kaolin. This was shipped to Philadelphia, where each ton was mixed with two tons of dilute sulphuric acid, and formed three tons of "alum cake." This brings from $25 to $35 a ton, and is sold mainly to paper manufacturers as a sizing for the better grades of wall and writing paper. The deposits are four miles from the B. & O. S. W. Railway, necessitating the hauling of the clay that distance over a rough road. The Salt Company finally began to make the alum salt from a deposit of cryolite which could be shipped to their works near Philadelphia in sailing vessels at a much reduced cost, and gradually abandoned the use of the kaolin. The land was then sold back to the former owner, Dr. Gardner, and the deposits have not been worked since 1891.

In the working of the deposit in the past, three slope shafts, each several hundred yards in length, have been put back into the hills in which it is found. The stratum of kaolin has a maximum thickness of 11 feet and a minimum of 4, the average being 5½ to 6 feet in the area worked over. The kaolin lies in a horizontal stratum like a vein of coal, and is mined in much the same manner, though with much less blasting. The overlying sandstone varies much in character. In some places it is a true conglomerate containing many small quartzose and other pebbles, cemented together with a material which, according to Professor Noyes, contains considerable amounts of alumina. In others it is the fine-grained, pinkish brown, shelly sandstone, noted above as forming the roof over similar deposits at Dover Hill. In places there are narrow cracks or crevices, extending a foot or more into the roof, which are filled with the kaolin. Again small, irregular masses of the kaolin are found, as a part of the conglomerate, at a height of six or eight feet above the main stratum.

In many places at the upper portion of the bed of kaolin, and lying immediately in contact with the roof, are masses of the semi-transparent,



MICROSCOPICAL SECTION OF KAOLIN FROM LAWRENCE COUNTY.

Magnified 60 diameters. Natural Light.

light green mineral known as allophane, in which the percentage of alumina and water are the same, and double that of the silica, as follows:

Water	40 per cent.
Alumina	40 "
Silica	20 "

On exposure to the air the water of crystallization shortly passes off and the mineral effloresces into a white powder, made up of particles resembling in a general way those of coarse corn meal.

The upper half of the kaolin stratum is mainly composed of a massive, snow-white clay, which has a smooth, unctuous feel. Associated with this, especially near its top, are occasional concretionary or nodular masses, often a foot or more in diameter, which, when broken, show a light blue lamellar center. Both of these forms disintegrate on exposure to the air into a rather coarse grained white powder. An analysis of an average sample of the massive variety made for this report by Professor Noyes* shows the following results:

Silica	44.75 per cent.
Alumina	38.69 "
Water	15.17 "
Ferric oxide	.95 "
Lime	.37 "
Magnesia	.30 "
Potash	.12 "
Soda	.23 "
Total	100.58 per cent.

The sum total of the impurities is thus seen to be less than two per cent. The quantity of iron is so small as to have no effect upon the color of the burned ware which is, if anything, whiter than the clay itself.

Like many similar kaolins, this is practically non-plastic; but by grinding very fine and then kneading, it can be made to assume a certain degree of plasticity. Maurice Thompson asserted that this kaolin does not contain the microscopic granular crystals which are characteristic of all non-plastic clays.† Prof. Erasmus Haworth, of Lawrence, Kan., a noted expert in the mineralogy of clays, has, however, proven their presence in quantities, as the accompanying photographic representation, kindly sent to this Department by him, will show. Of the kaolin, he

* "The mineral contains no titanium and less than one per cent. of it is insoluble, on treatment with sulphuric acid and sodium carbonate. It is a very nearly pure kaolin, for which the theoretical composition would be, from the formula, $Al_2Si_2O_7+2H_2O$, the composition being as follows:

Silica	46.51 per cent.
Alumina	39.53 per cent.
Water	13.96 per cent."

W. A. Noyes.

† Fifteenth Report Indiana Geological Survey, 1886, 39.

wrote as follows: "I have already studied Indianaite (the name given by Prof. Cox to the Lawrence County kaolin) a little, and find it is completely crystallized throughout, although grouped under *Halloysite* by Dana and given as non-crystalline."

The lower half of the stratum of kaolin in the Huron mines varies in color from a pale buff to a rich, deep brown. This is due to its being stained with the oxides of iron and possibly those of manganese and cobalt. Such a clay, while unfit for porcelain ware, can, however, be used in the making of certain grades of "alum salt", and for this purpose much of it has been utilized in the past.

The refractory properties of this clay are of the highest, as its composition shows. Mixed with a small percentage of a more plastic material as one of the purer underclays of the coal seams, it can be used in the making of the finer grades of retorts, glass-pots, glass-tanks, etc. Ground fine and pressed dry it will make the highest grade of fire-brick.

According to Dr. Gardner this kaolin is somewhat remarkable for the weakness of affinity existing between its silica and alumina. It will give up its alumina to acids or its silica to alkalies with great freedom until after it has been heated to redness and the chemically combined water is driven off, when it acts the same as other clays. On account of this weakness of affinity it is well suited for the making of such chemical compounds as the alum salts.

Thousands of tons of this purest of clays are visible in the mines which have been opened. The stratum thickens as progress is made further back into the hills. The deposit is not a local one covering a few rods or acres, *but square miles*, as evinced by outcrops which are known. There is enough in sight in the mines at this one deposit to last an average factory a hundred years, and not one one-thousandth of it has been exposed to view. There it lies, a great mineral resource of untold value, unworked. unutilized, awaiting only the coming of energy and capital to make it up into many kinds of products which are now brought into our State from distant lands.

DUBOIS COUNTY,

lying south of Daviess and Martin counties, comprises an area of 432 square miles. The eastern, and especially the northeastern townships, are broken with numerous hills and ridges, the Conglomerate Sandstone forming for the most part the surface rock. The western two-thirds is more level and underlain with the Coal Measure strata, though being deficient in railway facilities, but few mines are worked, and they only to supply the local trade. The county is abundantly supplied with water courses. The East Fork of White River forms the greater part of its northern boundary. Patoka River flows in a westerly direction through the center of the county and its numerous branches ramify through the eastern and southern areas.

The leading clay deposits visited were in the vicinity of Jasper and Huntingburgh. One-half mile north of the former place, Reider Hill rises 140 feet above the level of the Court House yard. Near its top an outcrop of soft, unctuous light-gray shale is exposed for a thickness of 23 feet along the roadside. In this hill are three veins of coal, the middle one averaging three feet in thickness. Two of these veins have been worked in several places by means of slope shafts, and the coal has been proven to be an excellent fuel. Beneath each of these three veins of coal is from 3 to 5 feet of a fine grained, very light colored fire clay, which will prove excellent for pottery or refractory purposes. The shale above noted can be made into either vitrified or pressed front brick of high grade; so that this hill, within one-half mile of the county seat, contains not less than 35 feet of good commercial clay and the fuel necessary for its burning. A railway switch can be readily constructed past the furniture factory in the east side of the town and up the valley to the foot of the hill, where there is an excellent site for a large factory.

Three-fourths of a mile west of Jasper, the "soapstone," or gray shale above mentioned, outcrops in numerous places along the roadside, and underlies the whole of the wooded tract of land known as "Military Park" (N. E. ¼ Sec. 34, Tp. 1 S., R. 5 W.). Several slope shafts have been put in in this vicinity and disclose a good quality of fire clay beneath the coal. Military Park is but three-fourths of a mile from the Jasper and Huntingburgh branch of the "Air Line" Railway, and a switch easily constructed and of sufficient grade to allow cars to run by gravity to the main line, could be built up the valley to the shale and clay. The entire area of Sec. 34 is probably underlain with these deposits. Jasper and vicinity is populated by a frugal, largely German population. The town is well supplied with schools and churches and is rapidly increasing in wealth and enterprise, several large business blocks and a system of water works having been constructed within the past year.

At Huntingburg, an important junction point on the "Air Line" Railway, there exists a large deposit of one of the best potter's clays known to occur in southern Indiana. For a number of years large quantities of it have been shipped by Bockting Bros. to potters at Evansville, New Albany, Louisville and other points along the "Air Line" Railway; and for 18 years it has been used in a pottery at Huntingburg. It is found beneath a thin vein of coal in Beeler's Hill, just north of Huntingburg (N. W. ¼ Sec 34, Tp. 2 S., R. 5 W.). To secure the clay a slope shaft has been put in by the Bocktings.

Two hundred yards northwest of the opening of this mine is an air shaft put down through the potter's clay by the Huntingburg Pressed Brick Company. From it the following section, disclosing the strata in that part of Beeler's Hill, was obtained:

1.	Surface and yellow clay	14 feet.	
2.	Blue argillaceous shale	16 feet.	
3.	Dark bituminous shale	2 feet.	
4.	Coal		11 to 14 in.
5.	Potter's clay (choice)	5 feet	10 in.
6.	Fire clay impregnated with small grains of iron ore	2 feet.	
7.	Soft gray argillaceous shale (exposed)	7 feet.	

All of these are valuable for manufacturing purposes. Only No. 5 has heretofore been shipped. It brings, on board the cars at mouth of shaft, 85 cents a ton.

The stratum of clay dips to the southwest, and the mine is, therefore, difficult to free from water. Miners are paid $1.50 per day, and furnished powder and tools, and each man gets out 10 to 12 tons of the clay daily. The stoneware made from this clay at Huntingburg and Evansville is strong, durable, and takes an excellent glaze. It does not air crack in drying or in cooling after being removed from the kiln. The composition of the clay, as shown in an analysis made for Bockting Bros. by Professor Noyes, is as follows:

Silica (total)	69.23	
Titanium oxide	1.50	
Alumina	18.97	
Water (combined)	5.46	
*Clay base and sand		95.16
Ferric oxide	1.57	
Ferrous oxide	.55	
Lime	.12	
Magnesia	.36	
Potash	2.27	
Soda	.33	
Fluxes		5.20

This shows a composition approaching very closely the average standard of stoneware clays (see p. 48), and proves the superiority of this clay for pottery purposes.

The Huntingburg Pressed Brick Company has recently erected a large and well equipped plant a short distance northeast of the shaft worked

* As the titanium oxide does not act as a flux I include it here.

by Bockting Bros. They make from the surface yellow clay a handsome and durable red front brick. This clay closely resembles the surface clay at Washington, Indiana, being like it, free from foreign matter and homogeneous in texture.

From the stratum of potter's clay this company is making a buff front brick, and from a mixture of the potter's clay and the underlying fire clay, containing small grains of iron ore, a speckled or Pompeii front brick which is in large demand. The small grains of iron ore in this lower stratum of fire clay are most probably the ferric or sesquioxide of iron (Fe_2O_3). These are reduced by the influence of the heat and gases of the kiln to ferrous oxide (FeO). When subjected to higher heat a fluxing action begins and causes a chemical union between the ferrous oxide and any free silica in the clay, producing a black ferrous silicate, which is not affected by higher heat. The black specks, ranging in size from a pin head to the cross section of an ordinary lead pencil, found in the Pompeii brick, are composed of this silicate. These brick bring from $25 to $30 per 1,000 at the factory, as against $10 to $12 for the buff, unspeckled brick. From the potter's clay (No. 5) this company makes the fire brick and floor tiling for their kilns. These stand up well under great heat and prove the high refractory grade of the clay as evinced by its chemical composition. Both the upper shale (No. 2) and the lower (No. 7) of the section at Beeler's Hill are suitable for vitrified products. The bottom six feet of No. 2 would probably have to be rejected on account of too high a percentage of bitumen. With these shales present in such large quantities, an addition for the purpose of making vitrified brick would, without doubt, prove a valuable adjunct to the plant already erected.

A short distance west of Bretzville (Sec. 32, Tp. 2 S., R. 4 W.), the "Air Line" Railway passes through a cut in which 20 feet of drab argillaceous shale is exposed. The sub-conglomerate coal "A" outcrops at several places in the same vicinity, and has beneath it a dark plastic underclay suitable for terra cotta.

Southwest of Ferdinand, in the S. ½ Sec. 34, Tp. 3 S., R. 4 W., are found large deposits of clay and decomposed iron ore suitable for the manufacture of mineral paints. The "Anderson Valley Mining Company" erected a mill at Ferdinand and worked these deposits for a number of years. Their products were of excellent quality, and for a time were much used, but a lack of railway facilities caused the abandonment of the enterprise. From a flinty limestone above a seam of coal on the same section a polishing powder called "tripoli" was obtained in quantity and put upon the market. The same material is found at several other points east of Ferdinand, notably in the N. W. ¼ Sec. 26, and the N. E. ¼ Sec. 13, Tp. 3 S., R. 4 W. Should the railroad projected between Rockport, Spencer County, and Mitchell, Lawrence County, be constructed it will pass through this region, and these resources will become of much value.

On the land of J. L. Schiller (S. E. ¼ of S. E. ¼ Sec. 6, Tp. 1 S., R. 3 W.), occurs an outcrop of pale blue fire clay 3½ feet thick. Through the lower part of it are scattered many crystals of selenite ($CaSO_4$), varying in size from 1 inch in length downwards. The owner burns the clay in a kiln, reducing these crystals to a powder, and then uses it as a fertilizer with good results. These crystals of selenite are found in numerous other deposits of fire clay east of Jasper, and have also been noted at other points in the State as at Mecca, Parke County, on the land of S. L. McCune. The crystals are oftentimes acicular, and radiating from a common center, form little rosettes which lie in great numbers on the exposed surface of the clays. With the exception of the one given above, no attempt, as far as known, has been made to utilize the clays containing them.

More than anything else Dubois County needs railways. When these are constructed new mines will be opened up, new deposits of shales and fire clays exposed, and it is to be hoped, put to ready use. Meanwhile those at Jasper and Huntingburg, mentioned above, merit further development. Either of them will furnish material of excellent quality, and in almost unlimited quantity for making vitrified brick, sewer pipe, pressed front brick, stoneware, hollow brick and terra cotta. Where clays suitable for such varied products occur in one bed, capital is bound in time to find them and put them to use. How soon that capital will be invested in their development depends solely upon the energies of the people in the towns near which the deposits lie.

PIKE COUNTY

is rich in undeveloped resources. The thickest veins of coal found in Indiana lie within its bounds. Vast beds of shale and clay cover and underlie these coals, bringing thus in close proximity the materials for fire-proof products and the fuel to manufacture them. Great beds of sandstone outcrop in the southeastern fourth, furnishing, with little labor, excellent material for foundations and walls. The soils of the western and northern parts of the county produce good crops of wheat, oats, corn and grass.

Pike County comprises 338 square miles. Daviess and Knox counties, to the north, are separated from it by the East Fork of White River and by White River proper. Patoka River flows west through the center of its area and furnishes the principal drainage outlet.

In the vicinity of Petersburg, the county seat, numerous mines have been opened, mostly by slope shafts. A few days before my visit an excavation for a reservoir had been made 50 feet south of the E. & I. station in the western part of the town. At the depth of 37 feet a vein of excellent coal was encountered, which will be hereafter mined. Careful measurements resulted in the following section:

1.	Surface soil and blue, mucky clay	16 feet.
2.	Blue argillaceous shale	6 feet 8 in.
3.	Blue limestone (fossiliferous)	10 feet 4 in.
4.	Black shale, with numerous "kidneys" of iron carbonate	3 feet 10 in.
5.	Coal	7 feet 1 in.

One and one-fourth miles northwest of the Court House is a mine operated by Jerome B. Borer. A stratum of under-clay four feet thick is found beneath the worked seam of coal. In the past many tons of this clay have been mined and hauled to Petersburg. There it has been made into strong and durable refractory bricks and flooring for kilns, grates, etc. Some of the brick have been used by the maker in the flue-arches of clamp kilns for twelve years, and others in the sides of a Eureka tile kiln for nine years, yet, to-day, they appear as good as new. The clay was delivered at the brick plant in town for 85 cents a ton. The brick made from it have sold at from $18 to $25 per thousand. But few have been made in the past three years, as the local demand for them has diminished, and no effort has been made to work up an outside market. The lower half of this vein of fire clay contains too many nodules of kidney iron ore to be of value.

At Sand Hill (N. ½ Sec. 22, Tp. 1 N., R. 8 W.), two miles north of Petersburg, the following section is exposed:

1.	Soil and sand	16 feet.
2.	Gray arenaceous shale	7 feet.
3.	Coal	3 feet 4 in.
4.	Fire clay	3 feet 6 in.
5.	Blue argillaceous shale, "soapstone"	8 feet.
6.	Gray arenaceous shale	6 feet 8 in.
7.	Dark limestone, fossiliferous	2 feet 4 in.
8.	Bituminous shale, containing nodules of pyrites	1 foot 8 in.
9.	Coal	2 feet 10 in.
10.	Fire clay	8 feet.

The two fire clays (Nos. 4 and 10) and the blue shale (No. 5) comprise together almost twenty feet of the best of material for manufacturing street brick, terra cotta, and many kinds of refractory products.

East of this, at Blackburn, on the E. & I. R. R., the fire clay beneath the seam of worked coal is hard and dark colored, with too many nodules of iron carbonate to be of use. The shale above is in thin layers and full of mica, rendering it almost worthless. This bed of micaceous shale outcrops along the railway to the southward for one-half mile or more, being overtopped for the greater part of this distance with a massive gray sandstone. It may be laid down as a general rule that when the shale splits, as this does, into layers or laminæ less than one-half an inch thick it is unfit for manufacturing purposes.

At the Smith mine (Sec. 13, Tp. 1 N., R. 8 W.) on land owned by Alexander Killion, Plainville, Daviess County, Indiana, the strata exposed are as follows:

1.	Soil and yellow clay	8 feet.
2.	Sandstone, micaceous, shaly	10 feet.
3.	Blue compact shale	14 feet.
4.	Coal	10 feet 2 in.
5.	Fire clay	??

The seam of coal at this point is the thickest I have seen in the State. Standing on the lower unworked part of the seam, one foot six inches in hickness, I could just reach with a miner's pick the roof at the top of the worked portion, the clear, unbroken seam of the latter being 8 feet 8 inches thick. If the mouth of the shaft had been made wide enough an ordinary two-horse wagon could have been driven into the mine and loaded directly from the vein. Although the seam of coal ranks among the best bituminous it is at present worked only to supply the local trade, the nearest railway switch being three-fourths of a mile distant. Only the upper part of shale No. 3 of the section given is fit for manufacturing, the lower six feet containing too much bitumen.

Southwest of Petersburg, on the land of Hosea Alexander, a new shaft had just been finished at the time of my visit. It was located one-half mile from the E. & I. Railway, and less than five feet south of the base line, in the N. E. ¼ Sec. 4, Tp. 1 S., R. 8 W. The strata here found were as follows:

1.	Soil and surface clay	10 feet.
2.	Shaly sandstone	6 feet.
3.	Blue arenaceous shale	4 feet.
4.	Coal	4 feet 6 in.
5.	Fire clay with numerous stigmaria	3 feet 4 in.

The fire clay found here is practically the same as that found at the Borer mine above mentioned. It has been tested by Mr. Reed, the brickmaker at Petersburg, and found to make a good grade of refractory brick.

Along the "Air Line" Railway in the southeastern part of Pike County are many outcrops of the sub-carboniferous coal "A" These for the most part occur in ravines running back from the Patoka River and its larger tributaries. The fire-clay beneath this coal is from 4 to 6 eet in thickness, light gray, silicious and suitable for the making of fire-brick and terra cotta. In numerous localities a bed of soft gray shale 12 to 15 feet in thickness separates the coal from the overlying sandstone. This shale is locally known as "soapstone," and combined with the fire-clay beneath the coal will make vitrified street brick of a superior grade. Such deposits of shale are found in the S. E. ¼ of Sec. 16 and the N. E. ¼ Sec. 23, Tp. 2 S., R. 7 W.

GIBSON COUNTY,

lying south of Knox and west of Pike and Warrick counties, is one of the richer agricultural counties of Southern Indiana. The Wabash River forms its western boundary and receives from the east the White and Patoka rivers. These, with their tributaries, drain the county and furnish a plentiful supply of running water. The soil of the western two-thirds is very fertile and produces some of the largest crops of corn and wheat grown in the State.

The Coal Measure rocks cover the surface of the county, but it is only along its eastern margin that the veins of coal outcrop, and there only in a few localities. The western three-fourths of the county is very similar to that of western Knox, the veins of coal of workable thickness being overlain with from 200 to 400 feet of alternating strata of shales and sandstones. Such formations, containing only a few thin seams of "rash" coals, are known as the Upper or Barren Coal Measures. They form the surface rocks in parts of Sullivan, Knox, Gibson and Vanderburgh counties and in all of Posey County.

At Princeton, the county seat of Gibson County, a number of bores have been recently put down to a depth of 600 to 800 feet, and one to a depth of 1,274 feet. The first vein of coal of workable thickness is found about 270 feet below the surface, and the second about 160 feet lower down.

At the time of my visit a shaft was being sunk in Sec. 1, Tp. 2 S., R. 11 W., one mile northwest of the Court House, to this lower vein. The first rash coal, 10 inches thick, had been found at a depth of 81 feet. Beneath this was seven feet of fire clay, the upper half of which is of excellent quality for terra cotta and similar products. At a depth of 277 feet the first workable vein, 3 feet 7 inches thick, was encountered. Above it was 40 feet of shale, the upper 18 of which was gray arenaceous, and showed a very marked, finely laminated structure, the laminæ being alternately light and dark in color. The lower 22 feet, resting directly upon the coal, was a blue argillaceous shale, very similar to that forming the roof of the worked seam at the Prospect Hill mine, Vincennes. While rather hard and massive in structure, it possesses the characteristics of a good material for vitrified products. Below the vein of coal was three feet of a tough plastic fire clay, which appears to possess high refractory properties, though as yet none of it has been tested. The shaft of this mine is by the side of the E. & T. H. Railway, and less than two hundred yards from the "Air Line." Switches from both roads will be constructed to it.*

The most available deposit of shale found near Princeton is just south of the "Air Line" shops, where an exposure has been made by the roadbed of the main line of that railway. This is in the N. E. ¼ Sec. 18 (2 S., 10 W.), and but one-third of a mile east of the E. & T. H. Railway. A section to the bottom of the exposure is as follows:

1.	Soil	2 feet 6 in.
2.	Yellow surface clay	10 feet.
3.	Sand rock—rotten, shelly	6 feet.
4.	Gray, argillaceous shale	8 feet.

The yellow surface clay (No. 2) is the fine grained silicious material so characteristic of the southern counties of Indiana. Fine pressed front brick are being made of it at Huntingburg, Jasper County. It burns to a handsome shade of red and makes a strong and durable brick. An analysis of a sample taken from the site of the above section was made by Prof. Lyons, of the State University, and its composition found to be as follows:

Silica	71.20	per cent.
Titanium oxide	.88	"
Alumina	18.56	"
Ferric oxide	1.34	"
Ferrous oxide	.15	"
Lime	.14	"
Magnesia	.52	"
Potash	.32	"
Soda	1.26	"
Water	6.30	"

For a surface clay this shows remarkable purity. While the percentage of free silica is high, that of lime, which is the most common and injurious impurity found in such clays, is very low.

*Since the above was written the lower vein of coal was reached at a depth of 440 feet. It is 6 feet 2 inches thick, and of good quality, as shown by the following analysis:

	Per cent.	
Fixed carbon	51.18	
Ash	11.02	
Solid, or coke-producing matter		62.20
Gas	32.71	
Water	5.09	
Volatile		37.80
Sulphur (separately determined)		1.38

The shale No. 4 is a drab or light gray material, showing occasional scales of mica and containing a rather large percentage of free silica. Its composition, as shown by an analysis made by Prof. Lyons, is as follows: *

Clay base and sand	87.33 per cent.
Fluxes	12.64 "

This shows a very close approximation to the standard average (see p. 54) of shales used for making paving bricks, and as far as such analysis and general appearance goes, it is well suited for that purpose The area covered by this shale deposit comprises 30 or more acres, and its situation is most favorable for the location of a combination factory for making both pressed front and paving brick.

In the southwestern part of Princeton, Dr. Wm. Kidd has for a number of years conducted the only brick yard found in that city. He makes ordinary and repressed soft mud brick from the yellow ochery surface clay described above. Beneath this stratum of clay at his yard is a deep red silicious clay, containing in places small geodes and pebbles of quartz and granite showing that a spur of some glacier has in the past extended this far south. From this red clay Dr. Kidd has made, as an experiment, very hard and durable brick which would, in the absence of shale brick, serve well as paving material.

Three miles east of Princeton, on the land of George Eaton (N. E. ¼ Sec. 10, 2 S., 10 W.), along the bottoms of Indian Creek, are outcrops of a vein of coal 14 inches thick, beneath which is an underclay 4 feet in thickness. This was used in making fire brick for the cupola furnace of a foundry at Princeton, and locally for the setting of brick, in grates, etc. It is said to possess high refractory qualities.

Near Bald Hill, north of Princeton one and one-half miles, on the land of Chas. Myers, is the outcrop of another "rash" vein of coal, whose underclay, 4 feet thick, has been used by Dr. Kidd for making fire brick for his kilns. These brick, according to Dr. Kidd, stood the heat as well as those bought at Freeman's Landing, Va., at $17 per thousand.

The only other outcrop of clay noticed during my short stay at Princeton was close to the "Air Line" Railway, by the side of a small stream, in the S. E. ¼ Sec. 1 (2 S., 11 W.), and a few hundred yards west of where the coal shaft, mentioned above, is being sunk. At this point an exposure of a good quality of shale has been made by the erosion of the water. The thickness of this stratum could not be ascertained.

In general it may be stated that wherever in Gibson County the "rash" coals come to the surface they will be found to be underlain with

* For complete analysis see table at end of chapter.

a clay suitable for the making of roofing tile, terre cotta, fire brick and, in some instances, potter's wares.

Southwest of Oakland City, in Sec. 24, Tp. 2 S., R. 9 W., Mr. Fred. Cotterill is operating a mine, the worked vein of coal being 135 feet below the surface. Beneath the coal is a stratum of dark-gray fire clay, 8 feet in thickness. This has been used with good results by Mr. Cotterill for making fire brick for boiler walls and furnaces. A switch of the "Air Line" Railway is completed to the mine.

VANDERBURGH COUNTY

occupies an area of 240 square miles, lying south of Gibson County, and between the counties of Warrick and Posey. Evansville, the county seat, is the second city in size in the State, and is especially noted for the number and magnitude of its manufactories. This is largely due to the excellence of its transportation facilities. Occupying an important site on the Ohio River, below interrupting rapids and ice, and near the outlet of the Wabash, Greene and Tennessee rivers, it has an important water communication with the states to the south and west, which has added much to its enterprise and growth. In addition to this, seven railways enter its bounds and furnish direct connection with the leading cities of the United States. Next to transportation, cheap and abundant fuel is the leading factor tending to promote manufacturing interests. Vanderburgh County lies wholly within the coal measures. A 4-foot seam of strong workable coal underlies nearly the whole area of the county. Numerous shafts have been sunk to it within the corporate limits of Evansville. These, and the mines at Newburgh and Oakland City, can furnish a cheap source of power for factories unlimited.

Three clay industries of large size are located at Evansville. In the next chapter these will be noted in detail. Attention is called to them here because one of them, the Evansville Pressed Brick Company, has been using on a large scale the shales found in the immediate vicinity of the city. This company began in 1890 to make vitrified brick for street paving purposes. For some time fire-clays from Lincoln City, Spencer County, and other points were used. Wishing a cheaper material the company began experimenting with the shales found along the low bluffs of Pigeon Creek, and finding them highly suitable for their purpose purchased a tract of land in the S. E. ¼ of the N. E. ¼ Sec. 24, Tp. 6 S., R. 11 W. The bed from which the shale is at present obtained is on this land, just at the outskirts of the city and one half mile from their plant, necessitating the hauling of the material in wagons for that distance. A section at the pit showed the presence of the following strata:

1.	Surface and yellow clay	5 feet.
2.	Drab argillaceous shale	14 feet.
3.	Blue arenaceous shale	5 feet.
4.	Sandstone	?

At intervals of one foot apart near the middle of the stratum of drab shale (No. 2) are three bands of kidney iron ore, each two inches in thickness. Otherwise this entire stratum is of most excellent material, being that soft, close textured, smooth variety of clay shale locally known as "soapstone." In the making of brick, either dry pressed or vitrified, all of this stratum is used, together with the overlying yellow clay and enough of the blue arenaceous shale to make one-fifth of the bulk. This makes a vitrified brick at once strong, tough and practically non absorbent, and one of which many millions have been sold within the past four years. An analysis of the mixture as it goes into the brick was made by Prof Noyes, and the composition found to be as follows:

*Clay base and sand	86.22
Fluxes	13.50

This proves the mixture well adapted for the uses to which it is put, as the composition is very close to that of the average composition of the Ohio shales used for such purpose. (See page 54.)

This deposit of shale, both drab and blue, covers a large area north and northwest of Evansville, and outcrops in a number of places along Pigeon Creek and its tributaries. An especially large and valuable bed of it is found in the S. E. ¼ of Sec. 8, Tp. 6 S., R. 10 W., about three-fourths of a mile east of Rose Hill cemetery. Along the borders of the stream known as Locust Lick it is especially noticeable. On the farm of Rudolph Fistle in the N. E. ¼ Sec. 14 (6 S. 11 W.) the drab variety is exposed to a thickness of 11 feet; and on the land of Jenner and Nugent, one-half mile farther east (N. E. of S. W. ¼ Sec. 13), is a bold bluff 30 feet in height, which is wholly made up of it. This is equal, if not superior in quality to that worked by the Evansville Pressed Brick Co., as no indications of iron kidneys were seen.

At the Crescent City Park, on the east bank of Pigeon Creek (S. E. ¼ Sec 24, Tp. 6 S., R. 11 W.), a bore was put down a number of years ago which resulted in a strong flow of artesian water. The record of that bore for the first 130 feet was as follows:

1.	Soil and surface clay	7 feet.
2.	"Soapstone"	24 feet.
3.	Gray sandstone	2 feet 6 in.
4.	"Soapstone" and shale	37 feet 6 in.
5.	Gray sandstone	1 foot.
6.	Coal	1 foot 6 in.
7.	Fire clay	6 feet.
8.	Gray shale	51 feet.

* For complete analysis see table at end of chapter.

This shows an inexhaustible supply of excellent clay within the city limits, for the "soapstone," of which more than 60 feet were gone through, is the best material known for paving and hollow brick, sewer pipe, pressed front brick and many kindred products.

West of this, near Babytown, is a high piece of ground known as "Law Hill" (N. E. of S. E. of Sec. 23), on the western slope of which Adam Helfrich has one of the largest brick yards in the vicinity of Evansville. The shale outcrops in this yard, and a well 34 feet deep did not reach the bottom of it. He has used it to some extent in making ordinary brick, and states that it is far superior to the surface clay for that purpose, but it requires different machinery and so its use was not continued. Outcrops on the east side of this hill, and on Wheeler's Hill to the northeast, showed that almost the whole of the east half of Sec. 23 is underlaid with this shale. These two hills are less than one-third of a mile from a railway, and the shale at both places can be secured by easy stripping. Indeed, these deposits contain enough of it to furnish paving brick for all southern Indiana for a hundred years.

At the First Avenue Coal Mine, located near Pigeon Creek in the western part of the city, the underclay beneath the worked seam is a very dark plastic material, which can be utilized in the making of terra cotta. It contains some pyrites which can be eliminated to a large extent by exposure to the atmosphere. The shale overlying the coal contains too much bitumen to be of value for vitrified products.

The fire clay found in Vanderburgh County, beneath coal "N," the top vein is of much better quality than that below the worked vein "M," but the upper vein is in most places too thin for profitable mining. If it and the clay were worked together, and the latter put to use, it would undoubtedly prove a paying enterprise.

The yellow surface clay of the county is, like most of that found south of the drift area, suitable in the highest degree for ordinary brick, and will make pressed front brick of a fair quality. Twenty-one brick yards were operated, in 1895, within a radius of two miles of the Court House at Evansville. The most of these were small establishments, where the output was molded by hand. Such competition could but result in very low prices, and the brick were being delivered at $4.50 per thousand at the time of my visit.

A sample of this yellow surface clay from the brickyard of Wm. Schnute in the northeastern part of the city of Evansville, is in a jar among the collections of clay made by Professor Gorby. On the jar is the following record of its analysis by Dr. J. N. Hurty:

Silica (total)	[illegible]	
Alumina	[illegible]	
Clay base and sand		[illegible]
Magnesia	[illegible]	
Lime	.54	
Ferric oxide	4.48	
Flaxes		[illegible]
Moisture and volatile		[illegible]

This shows great purity and a composition approaching closely some of the "fire" or under-clays of the coal seams. The low per cent. of iron oxide is surprising, as the color of the clay would denote much more.

WARRICK COUNTY

is situated east of Vanderburgh, and south of Pike and Gibson counties, and the Ohio River forms a part of its southern boundary. The county comprises an area of 388 square miles, and lies wholly within the Coal Measure formation. The land is, for the most part, well adapted to cultivation, large quantities of wheat, corn and hay being annually produced and shipped to markets on the Ohio River. Tobacco is one of the staple products grown, as high as eight million pounds having been raised in the county in a single season. The principal mines are in the vicinity of Boonville, the county seat, and Newburgh, the chief river town.

By the side of the Evansville Division of the "Air Line" Railway, one mile northeast of Boonville, is the mine of Goff & Kellar, in the shaft of which the following section is exposed:

1.	Soil and surface clay	12 feet.
2.	Shelly sandrock, with numerous small iron kidneys	3 feet.
3.	Dark shaly limestone, fossiliferous	13 feet.
4.	Black fissile shale	4 feet.
5.	Coal	6 feet 4 in.
6.	Fire clay	? ?

No one of these is suitable for manufacturing. The fire clay, the thickness of which I was not able to determine, is of a greenish gray tint, and contains so large a percentage of fluxes as to render it worthless. Brick made from it have been tested by L. Klostermier, of Boonville, in the floor and flue arches of clamp kilns. In a short time they began to swell up, then the surface melted and flowed like slag, and finally the whole body of the brick became black, porous, and lava-like in appearance

One-half mile farther east is the mine of the Lander, Wooley Co. The strata here are the same as at Goff & Kellar's, except that the shaly limestone is much thinner, and the vein of coal, 8 feet in thickness, is but 17 feet below the surface at the point where the slope shaft begins.

At the brick yards of L. Klostermier, and Henry Felwisch, in the northern part of the town of Boonville (N. ½ Sec. 26, Tp. 5 S, R 8 W.), an exposure of a soft gray unctuous "soapstone" has been made by the removal of the yellow surface clay. This stratum has been proven, by boring, to be from 7 to 12 feet in thickness. On the Felwisch yard the following section is exposed:

1.	Soil	1 foot 3 in.
2.	Yellow clay	6 feet 9 in.
3.	"Soapstone," with layer of iron kidneys in uppper 6 inches	7 feet.
4.	Sandstone	??

No use has been made of this soapstone. Mr. Klostermier has ground some of it and attempted to make drain tile, but it clogged the machine too badly. Mixed with a more silicious material as the overlying surface clay, it will undoubtedly prove suitable for vitrified products and hollow brick. Aside from the iron concretions found in its upper part the stratum is remarkably pure and homogeneous throughout.

At the old St. Elmo mine, three miles west of Boonville, on the "Air Line" Railway, a stratum of fire clay of excellent quality underlies the worked seam of coal. It is light gray, silicious, and, judging from appearance, of high refractory grade.

At Newburgh the principal mines are found just above the town along the Ohio River front, in Sec. 2, Tp. 7 S., R. 9 W. The top vein of coal, unworked, is underlain with about 2½ feet of fire clay, and below this is 20 feet of gray argillaceous shale. Both of these, singly or combined, are suitable for vitrified products. The main vein of Newburgh coal is found about 93 feet below the surface. The fire clay underlying it varies in thickness from 3 feet 6 inches to 4 feet 3 inches, and is suitable for terra cotta or sewer pipe.

Although many seams of coal and clay outcrop in the northern half of Warrick County, but few mines have been worked on account of a total lack of railway facilities. Until these are furnished the mineral resources of that section will remain practically undeveloped.

SPENCER COUNTY

is one of very irregular outline. Lying between Perry and Warrick counties, it is bounded on the north by Dubois County and on the south by the Ohio River. It comprises an area of 498 square miles, the most of which is covered with a soil of great fertility. The leading crops are corn, hay, tobacco and potatoes.

The northern two-thirds of the county is underlain with coal. The southern third has for its surface rock the conglomerate sandstone or millstone grit, which forms the high bluff along the Ohio River, on which Rockport, the county seat, is located. For that reason no clays of importance, other than those used for making ordinary soft mud brick occur in the immediate vicinity of Rockport.

The Eigenmann Contract Company have a large brick yard a short distance from the town, on which the following section was disclosed:

1.	Soil (stripped)	1 foot.
2.	Yellow surface clay	7 feet.
3.	Sand (bottom concealed)	20 feet.

The yellow clay is the characteristic surface clay of the driftless area of Indiana. It makes an excellent stock brick, and, as has been proven at Huntingburg, can also be made into a good grade of red pressed front brick. The sand (No. 3) of the above section is a good moulding material, and large quantities of it are annually shipped for that purpose to various towns on the "Air Line" Railway.

The mine nearest to Rockport, which is worked for coal, is 7 miles north, on the land of James Fisher (N. W. ¼ Sec. 16, Tp. 6 S., R. 6 W.). Here the vein of underclay is thin and of poor quality. Three miles nearer the town, on the land of Geo. Shrode (E. ½ Sec. 4, Tp. 7 S., R. 6 W.), is a thin seam of coal beneath which is a vein of much better "fire clay," 4 feet in thickness. It is fine grained, light colored and silicious, and appears in every way suitable for potter's use.

In the vicinity of St. Meinrad, in the northeastern part of the county, a seam of block coal called "I" by Prof. Cox, outcrops in a number of places. It is underlain with a deposit of fire-clay from 3 to 5 feet in thickness, which is suitable for terra cotta and sewer pipe, and in some instances for potter's use. The Cincinnati, Rockport & Southwestern Railway, on which much work was done last season, and which will eventually be constructed, runs through St. Meinrad, and when completed will furnish an outlet for these mineral resources

One and one-fourth miles southeast of Lincoln City the Cannelton branch of the "Air Line" Railroad runs through a large shale deposit.

A cut 30 feet deep was made for the roadway, which exposes the following section:

1.	Soil and surface clay	4 feet.
2.	Light drab argillaceous shale	10 feet.
3.	Concretions of kidney iron ore	4 in.
4.	Dark gray argillaceous shale	16 feet.

With the exception of the 4-inch band of iron ore this deposit of shale is free from impurities. It is soft, gritless, and weathers, in places, into quadrangular pieces an inch or two in size, indicative of its superior grade. An analysis of a mixture of the two colors of this shale, made by Prof. Noyes, shows the following composition:*

Clay base and sand	84.45 per cent.
Fluxes	14.43 "

This shows but a slight variation from the standard average composition of shales suitable for vitrified products (see p. 54), and proves the chemical fitness of this deposit for that use.

This stratum of shale overlies a large area south of Lincoln City. Exposures from 15 to 30 feet in thickness are made in it by the Rockport branch of the "Air Line" Railroad between Lincoln City and Rockport Junction, and also one-half mile south of the latter point. Other outcrops are found on the Cannelton branch between the big cut above mentioned and Buffaloville, and between the stations of Lamars and Evaston.

An excellent grade of coal is mined by the Henry Shafer Company, one mile south of Lincoln City and one-fourth of a mile north of the "shale cut." The vein of coal lies at a depth of 23 feet. It is 3½ feet thick and overlies a bed of fire-clay which averages about 5 feet in thickness. Much of this has to be removed to make height. One thousand or more cars of it were shipped in 1891 and '92 to Evansville and made into vitrified brick by Lant, Morris & Co. When this firm discovered and began to utilize the shale near Evansville the shipping of the fire-clay was discontinued. It is now raised and thrown on the dump or stored in the worked out areas. It costs 30 cents a ton to handle it and when shipped brought 50 to 65 cents on the cars at the mine. This underclay is a dark gray, fine-grained material containing too large a percentage of fluxes for refractory products, but well suited for the making of vitrified wares or terra cotta. It is co-extensive with the vein of overlying coal, which is worked at a number of points in Clay and Hanover townships.

Lincoln City is a growing town and an important junction point on the "Air Line" Railway. With large deposits of shale, fire-clay and coal in its immediate vicinity, and with good railway facilities, it offers excellent advantages for the location of a great clay industry.

*For complete analysis see table at the end of this chapter.

PERRY COUNTY

lies south of Dubois and Crawford counties, and has a frontage of almost fifty miles on the Ohio River. Anderson Creek forms the greater part of its western boundary, and the numerous tributaries of this stream and the Ohio furnish an excellent system of drainage. The county is a large one, comprising an area of 380 square miles, more than three-fourths of which is covered with the millstone grit or conglomerate sandstone, which is here represented by sandy shale, flags, and a massive sandstone containing quartz pebbles. With the exception of the bottoms along the Ohio River and the larger streams of the interior, the soil is very poor, and the surface of the county exceedingly rough and broken.

The Coal Measures come to the surface in the southwestern fourth and along the Ohio River between Rock Island and the mouth of Anderson Creek, and it is in this region that the clays and shales, herein referred to are found.

Perry County has long been noted for its clay industries. The first pottery of importance in the State of Indiana was located, in 1834, on the banks of the Ohio River, a short distance above the town of Troy. Jas. Clews, a wealthy individual of Liverpool, England, had previously visited the place and made a careful investigation of the clays underlying the seams of coal. From the crude tests which he made he believed them to be fitted for making a light colored grade of porcelain ware. Returning to England he organized a colony of more than 600 persons, many of whom were skilled potters. These he brought to Troy, and, burning ordinary brick for factories and dwellings, and fire brick for kilns, soon had a large industry in operation. To this he gave the name of the "Indiana Pottery Company." Some of the buildings erected were two stories in height and more than 200 feet long.

Unfortunately the clays at Troy proved unfit for the making of white ware; and the company had to ship in lighter clays and mix with them and content itself with manufacturing a yellow or Troy ware, which, in time, came to be much used in southern Indiana. This was, however, unsatisfactory to the leading members, and about 1840 the pottery was abandoned and allowed to go to ruin.

In 1863 a pottery was started on a small scale in one of the old buildings by B. Hincho. Some years later he abandoned this site and erected a new pottery in the town of Troy, where he manufactured from the underclay of the top vein of coal, a mahogany colored Rockingham ware until 1892, when old age caused him to desist. As a practical potter of long experience, Mr. Hincho claims that the clay found in the vicinity of Troy, and used by the Indiana Pottery Company and himself, can not be excelled for the making of terra cotta, ordinary stone ware, or the darker and more expensive Rockingham ware, but by itself burns too dark for the "yellow ware" such as the old company made. In 1865, Samuel Wilson started a pottery in the town of Troy, which he operated until his death in 1891. He made both yellow and Rockingham ware, the former from clay shipped in from Ohio which closely resembles the potter's clay found at Clay City, Indiana.

Near the site of the factories of the old Indiana Pottery Company, one-half mile above Troy, the shaft of the Bergenroth Bros. coal mine is located. One hundred yards east is the clay-pit of the old company. The following connected section was obtained at this point, beginning on the slope of the hillside (N. E. ¼ Sec. 13, Tp. 6 S., R. 4 W.), a few yards west of the section line which runs through the old pit:

1.	Soil and yellow surface clay	17 feet.
2.	Shaley sandstone	10 feet.
3.	Black fissile shale	5 feet.
4.	Coal (top vein)	6 in.
5.	Potter's clay	6 feet 4 in.
6.	Sandstone	33 feet.
7.	Coal	3 feet 2 in.
8.	Fire clay	??

According to Mr. Hincbo, the vein of potter's clay No. 5, becomes thicker farther back under the hill, and at the point worked by him, a few hundred yards east of Troy, was fully 12 feet in thickness. It is an exceeding close grained, light colored clay and stands up well under heat sufficient to melt the mixture of lead oxide, manganese and sand used in glazing the Rockingham ware. It is practically the same clay as is used at Cannelton, an analysis of which is given below.

The coal (No. 7) is the vein mined by Bergenroth Bros., and is the same seam as is worked at Cannelton. It is not a cannel coal but a semi-caking bituminous, and ranks high as a fuel. It is mostly sold to steamboatmen on the river, and is used by the engines on the Cannelton Branch of the "Air Line" R. R. This road runs within 20 feet of the shaft, and directly past the outcrops of clay mentioned above, passing over some of the foundations of the old pottery, which are buried beneath the soil washed down from the adjacent hillsides.

In 1862 Clark Bros. established at Cannelton, the present county seat of Perry County, a factory for the manufacture of sewer pipe. This for more than thirty years was the only establishment of its kind in the State. Ten years later Wm. Clark erected by the side of the sewer pipe factory a large stoneware pottery. Both of these are still operated, and the latter is the largest concern of its kind in Indiana. The clay used in both factories is the underclay found so extensively in the vicinity of Cannelton beneath the top coal. That at present used is hauled in wagons from a point one mile northeast of the town, where the vein of clay is from four to five feet in thickness. In many places the coal is absent, and the clay is obtained by stripping the surface soil to a depth of from one to six feet.

The upper half of the vein, a light gray plastic clay of very fine texture, is used mostly for stoneware. Care must be taken in selecting it, however, as in some places it contains particles of pyrites, which, after burning, cause a flaking of small pieces from the surface of the ware, and so render it unsalable. The lower half of the vein is coarse-grained and has more of a reddish-yellow tinge, due to a larger percentage of iron oxide. It is better suited to the making of sewer pipes, as it vitrifies at a lower temperature than the upper, and burns to a darker color. No trouble with the "poppers" (as Mr. Clark calls them), or particles of iron pyrites, is experienced in the making of sewer pipe. This clay resembles shale somewhat in possessing a laminated appearance, but that it is a true fire clay of good refractory grade is shown by the following record of analysis made by Dr. Hurty of a sample from the upper part of the stratum:

Silica (total)	65.830	
Alumina	22.940	
Clay base and sand		88.770
Magnesia	.858	
Lime	.308	
Ferric oxide	2.640	
Fluxes		3.806
Moisture and volatile		7.434*

The surface of the sewer pipes made from the more impure lower portion of the clay stratum are glazed with salt, and become a light reddish brown in color. The pipes are hard, close-grained, very strong, perfect in form, and free from cracks and flaws.

The same stratum of underclay is used by the Cannelton Stoneware Company, which began operations in 1892 This company makes annually 150,000 gallons of stoneware, and finds the upper portion of the vein of clay admirably suited for the purpose.

Neither this company nor Mr. A. D. Clark make any attempts to wash this clay before using, it being simply ground by steam power in a wet pan or "tracer."

Mr. O. C. Lee, the Superintendent of the new company, has made some private tests which go to prove the value of a better system of preparing the clay. He showed me samples of vases and jars made from

*This probably includes 1 or 2 per cent. of potash. Compare the second column of this analysis with the standard average of Ohio stoneware clays given on page 48.

the washed clay, which were superior in design and finish. They were unglazed and when burned were of the peculiar stone-gray color of the raw material. They prove this clay, when properly prepared, to be well suited for the finest of decorative work. If washed before being made into stoneware, a much better quality of the latter could be made, and the increased price which it would readily bring would more than repay the extra expense of preparation.

The American Cannel Coal Company owns several thousand acres of land adjoining Cannelton on the north and east, and for years has carried on the mining of coal and the quarrying of sandstone on an extensive scale. The main vein of coal has been worked at a number of places, mostly by slope or drift shafts. The following connected section, obtained one and one-fourth mile east of Cannelton, on the S. E. ¼ of the N E. ¼ Sec. 10, Tp. 7 S., R. 3 W., may be taken as representing the average sequence of the strata through the worked seam of coal over a large area of the company's land:

1.	Soil and yellow clay	6 feet.
2.	Gray arenaceous shale	14 feet.
3.	Sandstone	8 feet.
4.	Blue arenaceous shale	11 feet.
5.	Coal (top vein)	1 foot to 18 in.
6.	Potter's clay	4 to 6 feet.
7.	Blue argillaceous shale	34 feet.
8.	Black bituminous shale	1 foot 6 in.
9.	Coal (main vein)	4 feet.
10.	Fire-clay	5 feet.
11.	Sandstone	20 feet.

Large quantities of shale (No. 7) and fire-clay (No. 10) have to be handled each year to make height in the rooms and entries of the mines. Neither of these have heretofore been put to use, though excellent sample, dry-pressed front brick have been made from them for the company. Shale No. 7 is a close-grained material very free from impurities. Its composition, as shown by an analysis made for this report by Prof. Noyes, shows the presence of: *

Clay base and sand	87.08 per cent.
Fluxes	12.34 "

This proves its chemical fitness for making vitrified products of many kinds; as the percentages given are very close to those of the average shale used for such products. (See p. 54.)

The fire clay (No. 10) burns to a handsome buff color and will doubtless make good terra cotta, or can be mixed with the shales to make paving brick. It contains too great a percentage of fluxing impurities to

* For complete analysis see table at end of chapter.

make refractory wares, as the following composition from analysis made by Prof. Noyes will show: *

Clay base and sand	87.15 per cent.
Fluxes	10.30 "

The yellow surface clay, which crowns the hills about Cannelton to a depth of 6 to 8 feet, is a superior article of its kind. The Cannelton Stoneware Company is making from it ordinary soft mud brick, which are but little inferior in appearance to some of the pressed front brick used in our cities. Mr. George Hufnagle, of Cannelton, has had sample, dry-pressed brick made from it which were very handsome in appearance. From deposits of shale and fire-clay on his farm (Sec. 9, Tp. 7 S., R. 3 W.) he has had other samples burned—the shales making a dark maroon brick which can not be excelled in quality, and the fire-clay a fair grade of buff front brick.

All in all, the clays found at available points in Perry County are excellent in quality, and in quantity practically inexhaustible. From them ordinary building brick, sewer pipe, stoneware, vitrified drain tile and Rockingham ware, all of *good quality, have been made in the past*, while paving, pressed front and hollow brick, and terra cotta can undoubtedly be made. Fuel of excellent quality, awaiting only the pick of the miner, underlies these clays. The Ohio River furnishes an ever-ready means of transportation, where not one company, but many, compete for freight, and so keep the rates at a very low figure; while the "Air Line" Railway has a branch line passing within one-half mile of all the chief clay deposits. With these facilities present no better site for the location of large clay factories exists in southern Indiana. The one thing lacking is a railway running northeast from either Cannelton or Tell City via Bloomington, Monroe County, to Indianapolis. Such a road would pass through the main oölitic limestone district of the State, and would open up a vast territory rich in many kinds of undeveloped resources.

* * *

This completes the list of counties comprised in the area covered by this report. As before stated, attention has been called only to the larger and more available deposits of commercial clays found within their bounds. The presence in large quantities of the raw materials suitable for making every kind of clay product used in Indiana, with the exception of some of the finer clays used in the better grades of terra cotta, encaustic tile and china ware, has been shown. The clays for the cheaper and vastly more used products, millions of dollars worth of which are annually imported into the State, are lying undeveloped and

* For complete analysis see table at end of chapter.

surrounded in most instances with the fuel necessary for their burning. With these resources present why should Indiana be behind the other States in clay manufacturing? Why should she make only 5 per cent. of the total value of clay products made in the United States, when Ohio and Illinois, with no more extensive or better beds of the raw material, make respectively 16 and 13 per cent.?

The people of this State are not awake to the opportunities and advantages in their midst. The majority of the clay industries which have started up at Brazil, Veedersburg, Terre Haute and elsewhere within the past five years are owned by parties outside of Indiana, and the profits accruing, which are large, go mostly without her bounds. As was well said by the superintendent of one of the largest of these factories (himself an Ohio man and the factory owned by Ohio capitalists): "The people of Indiana don't seem to know a good thing when they have it. They wait for outsiders to come in, gain possession of it and make it known to them, and then, too late, they realize its importance." Home factories should be erected, should be protected, should be patronized, for in such a way only can the future wealth and welfare of the State be increased, and plentiful labor be provided for her working-men.

Analyses of Carboniferous Shales.

	1		2		3		4		5		6		7		8		9		10	
	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.
Silica (SiO_2)	56.62		59.55	35.98	61.46	33.98	65.87	46.10	65.78	43.25	55.09	22.48	59.77	31.87	59.02	26 13	58.83	29.16	61.05	27.10
Titanium oxide (TiO_2)			1.00		1.20		1.10		1.00		1.20		.80		1.10		.70		1.20	
Alumina (Al_2O_3)	21.63		16.21	.39	16.54	1.72	14.06	2.63	14.79	2.54	20.76	.45	20.60	1.66	20.93	.66	22.34	1.81	21.46	.35
Water (combined)	6.53		5.62		5.09		4.59		4.98		7.01		4.53		7.59		5.22		6.94	
Clay base and sand	84.78		82.38		84.29		86.22		86.55		84.06		85.70		88.64		87.09		90.65	
Ferric oxide (Fe_2O_3)	7.08		2.18		3.77		6.23		8.03		3.00		2.22		4.45		6.13		5.57	
Ferrous oxide (FeO)			7.13		3.71		1.37				4.01		3.70		1.56		1.44		.71	
Lime (CaO)	1.11		.75		.66		.39		.54		1.51		.64		.51		.49		.25	
Magnesia (MgO)	1.41		1.58		1.81		1.54		1.42		1.18		1.98		1.66		1.56		.70	
Potash (K_2O)	3.14		2.81	.05	3.28	.82	2.66	1.21	2.82	1.13	2.36		3.10	.88	2.92	.31	4.18	.14	2.34	.04
Soda (Na_2O)	.48		.28		1.09		1.31		.97		.34		.85		.41		.63		.30	
Fluxes	13.22		14.73		14.32		13.50		13.78		12.40		12.49		11.51		13.43		9.87	
Carbon dioxide (CO_2)			3 15		1.45				.26		3.04		.90							
Total	98.01		100.26	36.42	100.06	36.52	99.72	49.94	100.59	46.92	99.50	22.93	99.09	34.41	100.15	27.10	100.52	31.11	100.52	27.49

Rational Analyses of Above Shales.

	1		2		3		4		5		6		7		8		9		10	
Quartz			34.61		27.94		36.87		34.34		20.90		26.04		23.82		22.81		25.87	
Feldspathic detritus			1.81		8.56		13.07		12.58		2.03		8.37		3.24		8.30		1.62	
Ferrous carbonate			8.61		3.82						6.46		2.37							
Magnesium carbonate									.50		1.13									
Clay substance			54.97		59.68		50.06		52.58		69.48		63.22		72.90		68.89		72.51	

Composition of Clay Substances of Above Shales

	1		2		3		4		5		6		7		8		9		10	
Silica (SiO_2)			42.10		45.94		39.71		42.38		47.28		44.05		44.83		42.71		46.47	
Titanium oxide (TiO_2)			1.80		2.00		2.21		1.88		1.74		1.26		1.59		1.02		1.64	
Alumina (Al_2O_3)			28.16		21.63		24.15		23.04		29.41		29.91		27.63		29.55		28.90	
Ferric oxide (Fe_2O_3)			3.92		6.30		12.50		15.10		4.35		3.51		6.06		7.39		7.62	
Ferrous oxide (FeO)			3.56		2.24		2.76						3.74		2.13		2.08		.97	
Lime (CaO)			1.35		1.10		.79		1.01		2.19		1.01		.70		.71		.34	
Magnesia (MgO)			2.84		3.03		3.10		2.22		.92		3.13		2.26		2.25		.96	
Potash (K_2O)			5.06		4.44		2.92		3.18		3.42		4.90		3.98		5.86		3.20	
Soda (Na_2O)			.50		1.82		2.64		1.82		.50		1.34		.58		.91		.40	
Water (H_2O)			10.11		8.50		9.22		9.37		10.16		7.15		10.53		7.52		9.50	

Analyses of Carboniferous Shales—Continued.

	11		12		13		14		15		16		17		18		19	
	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.
Silica (SiO_2)	56.68	35.53	53.26	30.17	64.05		46.07	26.33	56.32	23.47	55.31	31.67	62.04	43.58	67.82	52.63	68.46	50.63
Titanium oxide (TiO_2)	.90		1.05		1.00		1.19		1.07		1.15		1.30		1.10		1.49	
Alumina (Al_2O_3)	20.33	1.62	25.77	.46	16.00		24.22	2.97	24.34	2.93	22.46	5.62	18.49	3.70	13.60	3.97	16.08	3.72
Water (combined)	6.54		7.00		3.79		9.76		6.33		7.48		6.50		9.72		7.04	
Clay base and sand	84.45		87.08		84.84		81.24		88.06		86.40		87.33		92.24		93.07	
Ferric oxide (Fe_2O_3)	4.35		3.32		.89		9.65		5.60		7.18		7.54		4.04		1.92	
Ferrous oxide (FeO)	3.69		3.82		5.85		.34		.24		.23		.06		.45		.06	
Lime (CaO)	.57		.32		.42		.19		.31		.66		.16		.57		.99	
Magnesia (MgO)	2.04		1.90		2.00		1.31		.51		.93		.91		.44		.05	
Potash (K_2O)	3.15	.94	2.54	.35	2.59		1.66		2.85		2.05		.93		1.68		1.31	
Soda (Na_2O)	.63		.44		1.19		2.76		2.34		2.06		2.04		1.18		2.40	
Fluxes	14.43		12.34		12.94		15.91		11.88		13.11		12.64		8.36		6.73	
Carbon dioxide (CO_2)	.47		1.10		2.68		2.87				1.24							
Total	99.35	38.09	100.52	30.98	100.46		100.02	29.30	99.94	26.40	100.75	37.29	99.97	47.28	100.60	56.60	99.80	54.35

Rational Analyses of Above Shales.

	11		12		13		14		15		16		17		18		19	
Quartz	29.85		28.66				15.91		13.19		11.91		30.60		38.70		37.58	
Feldspathic detritus	8.24		2.32				13.39		13.21		25.38		16.68		17.90		16.87	
Ferrous carbonate	1.23		2.90				.54				.37							
Magnesium carbonate																		
Clay substance	60.68		66.12				70.72		73.54		63.46		52.69		44.00		45.35	

Composition of Clay Substances of Above Shales.

	11		12		13		14		15		16		17		18		19	
Silica (SiO_2)	35.83		34.54				27.91		44.53		37.25		35.03		34.55		39.31	
Titanium oxide (TiO_2)	1.52		1.58				1.68		1.45		1.81		2.47		2.50		3.28	
Alumina (Al_2O_3)	31.69		37.98				30.04		29.11		26.53		28.07		21.88		27.25	
Ferric oxide (Fe_2O_3)	7.37		4.98				13.64		7.61		11.31		14.31		9.18		4.23	
Ferrous oxide (FeO)	3.27		3.03				.48		.32		.36		.11		1.02		.13	
Lime (CaO)	.97		.48				.26		.42		1.04		.30		1.29		2.18	
Magnesia (MgO)	3.46		2.95				1.85		.73		1.46		1.73		1.00		.11	
Potash (K_2O)	3.74		3.30				2.34		3.87		3.23		1.77		3.82		2.84	
Soda (Na_2O)	1.07		.66				3.90		3.18		3.24		3.87		2.68		5.28	
Water (H_2O)	11.08		10.50				13.80		8.60		11.78		12.34		22.69		15.52	

REMARKS ON THE SHALE ANALYSES.

No. 1. Average of ten analyses of shales used in the manufacture of paving brick and sewer pipe in the State of Ohio. Adopted as the standard for this report.

No. 2. Mixture of shales and surface clay as used by Wabash Clay Co., Veedersburg, Fountain County, Indiana, in the making of paving blocks. Average sample.

No. 3. Mixture of shales and small amount of surface clay, as used by the Clinton Paving Brick Co., Clinton, Vermillion County, Indiana, for the making of paving brick. Average sample.

No. 4. Mixtures of shales and surface clay as used by the Evansville Pressed Brick Co., Evansville, Vanderburgh County, in the making of paving and dry-pressed brick. Average sample.

No. 5. Mixture of shales Nos. 3 and 4 from the clay pit of the Cayuga Pressed Brick Co., Cayuga, Vermillion County, Indiana. Used for making red dry-pressed brick. Average sample.

No. 6. Bastard shale, No. 5, from the pit of the Cayuga Pressed Brick Co., Cayuga, Vermillion County, Indiana. Used in the making of buff dry-pressed brick. Average sample.

No. 7. Shale No. 2, from the land of S. L. McCune, Mecca, Parke County, Indiana. Average sample.

No. 8. Shale No. 9, from the land of S. L. McCune, Mecca, Parke County, Indiana. Average sample.

No. 9. Shale No. 5, from the land of S. L. McCune, Mecca, Parke County, Indiana. Average sample.

No. 10. Shale from the land of H. T. Thorp, near Terre Haute, Vigo County, Indiana.

No. 11. Mixture of shales from railway cut near Lincoln City, Spencer County, Indiana. Average sample.

No. 12. Shale No. 7, from above the main vein of coal worked by the American Cannel Coal Co., Cannelton, Perry County, Indiana.

No. 13. Shale from above the worked vein of coal, Prospect Hill mine, Vincennes, Knox County, Indiana.

No. 14. Shale No. 6, from the land of Joseph Burns, West Montezuma, Vermillion County, Indiana. Average sample.

No. 15. Shale No. 11, from the land of Joseph Burns, West Montezuma, Vermillion County, Indiana. Average sample.

No. 16. Shale No. 8, from above the worked vein of coal, Shaft No. 1, Island Coal Co., Linton, Greene County, Indiana. Average sample.

No. 17. Shale from near "Air Line" shops, Princeton, Gibson County, Indiana. Average sample.

No. 18. Shale from the land of Frank Landers, near Stone Bluff, Fountain County, Indiana.

No 19. Shale from the land of J. W. Shuster, near Stone Bluff, Fountain County, Indiana.

***

Analysis No. 1 is taken from Prof. Edward Orton's (Jr.) report on the "Clay-Working Industries of Ohio" (Vol. VII, Ohio Geol. Surv., 1893, 133). Analyses Nos. 2 to 13, inclusive, were made for the present report by Prof. W. A. Noyes, of the Rose Polytechnic Institute, Terre Haute, Indiana. These analyses were in each case based on the sample dried at 135° C. The parts marked "insoluble" were found to be insoluble in acids and sodium carbonate.

In the "rational analyses" the quartz was determined by subtracting $3\frac{51}{100}$ times the insoluble alumina from the insoluble silica. The remainder of the insoluble portion was counted as "feldspathic detritus" The general method of analysis followed was that given in Wagner's Chemical Technology.

Analyses Nos. 14 to 19, inclusive, were made for this report, after the burning of the Polytechnic laboratory, by Prof. Robert Lyons, chemist at the State University, Bloomington, Indiana, who was assisted by the following students: Messrs. P. A. Yoder, H. A. Bordner, O. W. Brown and H. G. Reddick. The methods followed by Professor Lyons were essentially the same as those used by Professor Noyes.

Analyses of Under-clays of Coal Measures.

	1		2		3		4		5		6	7	8
	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Insoluble.	Total.	Total.	Total.
Silica (SiO_2)	69.23	41.22	57.57	29.00	54.46	20.28	63.00	27.05	83.44	76.90	68.13	54.53	58.78
Titanium oxide (TiO_2)	1.50		1.10		1.20		1.10		1.29			1.26	.94
Alumina (Al_2O_3)	18.97	.36	21.70	.30	25.71	.17	23.57	.21	10.36	8.71	20.80	27.88	26.47
Water (combined)	5.46		6.78		8.59		6.45		3.15		5.72	8.87	9.96
Clay base and sand	95.16		87.15		89.87		94.12		98.24		94.65	92.54	96.15
Ferric oxide (Fe_2O_3)	1.57		2.26		5.51		1.87		.27		1.20	2.41	1.22
Ferrous oxide (FeO)	.55		4.11		.91		.46		.28				
Lime (CaO)	.12		.32		.24		.44		.36		.42	.42	.59
Magnesia (MgO)	.36		1.12		.83		.89		.14		.37	.68	.32
Potash (K_2O)	2.27	.05	2.16	.24	2.68	.07	2.40	.05	.03		2.28	3.31	.99
Soda (Na_2O)	.33		.33		.33		.29		.71		.27	.12	
Fluxes	5.20		10.30		10.50		6.35		1.79		4.54	6.94	3.12
Carbon dioxide (Co_2)			1.73										
Total	100.36	41.63	99.18	29.54	100.37	20.52	100.47	27.31	100.03	85.61	99.19	99.48	99.27

Rational Analyses of Above Under-clays.

	1		2		3		4		5		6	7	8
Quartz	39.36		27.95		19.69		26.31		46.33				
Feldspathic detritus	1.67		1.95		.83		1.00		39.28				
Ferrous carbonate			3.65										
Clay substance	58.37		66.81		79.48		72.69		14.39				

Composition of Clay Substances of Above Under-clays.

	1		2		3		4		5		6	7	8
Silica (SiO_2)	47.70		43.29		42.79		49.15		45.44				
Titanium oxide (TiO_2)	2.55		1.67		1.50		1.50		8.96				
Alumina (Al_2O_3)	31.67		32.94		31.95		31.93		11.46				
Ferric oxide (Fe_2O_3)	2.67		3.42		6.89		2.54		1.87				
Ferrous oxide (FeO)	.93		3.32		1.14		.63		1.94				
Lime (CaO)	.21		.48		.30		.61		2.50				
Magnesia (MgO)	.62		1.70		1.04		1.21		.97				
Potash (K_2O)	3.78		2.91		3.35		3.23		.20				
Soda (Na_2O)	.57		.50		.41		.38		4.93				
Water (H_2O)	9.30		10.27		10.63		8.82		21.83				

REMARKS ON THE UNDER-CLAY ANALYSES.

No. 1. Under-clay No. 5, from mine owned by Bockting Bros., Huntingburgh, Dubois County, Indiana. Used for stoneware at Huntingburgh, Evansville, etc.

No. 2. Under-clay from beneath the vein of coal worked by the American Cannel Coal Co., Cannelton, Perry County, Indiana.

No. 3. Under-clay No. 8, from the land of S. L. McCune, Mecca, Parke County, Indiana.

No. 4. Under clay No. 16, from the land of S. L. McCune, Mecca, Parke County, Indiana.

No. 5. Under-clay No. 10, from the land of Joseph Burns, West Montezuma, Vermillion County, Indiana. Used in the making of fire bricks. Average sample.

No. 6. Average of stoneware clays selected from the ground clays used in several of the large Akron, Ohio, stoneware factories, and then mixed.

No. 7. Under-clay used in large sewer pipe factory at Walker's Station, Columbiana County, Ohio. (Lord, Chemist.)

No. 8. Ballou fire clay, from Muskingum County, Ohio. Used as a bond for flint clays in forming high grade refractory materials. (Lord, Chemist.)

* * *

Analyses Nos. 1 to 4 inclusive were made for this report by Prof. W. A. Noyes. No. 5 was made by Prof. Robert Lyons, Bloomington, Indiana. Nos. 6, 7 and 8 were taken from Professor Orton's report on the "Clay-working Industries of Ohio."

CHAPTER III.

THE CLAY-WORKING INDUSTRIES OF THE COAL-BEARING COUNTIES OF INDIANA.

The clay-working industries of western and southwestern Indiana are yet in their infancy. Previous to 1890 but six clay factories were in existence in the 18 counties covered by this report, the value of whose annual output was more than $5,000. To-day there are 24 in the area mentioned, whose yearly output is more than $10,000 each, and of nine of these it is more than $50,000 each. There is room for five times as many without overcrowding or overdoing the business, for the number and variety of clay products is increasing at a marvelous rate, while the growth of the country and the rapid disappearance of the forests is ever widening the demand and opening up new markets.

Eleven years ago the State Geologist of Ohio, foreseeing the coming increase in the use of clay for manufacturing purposes, investigated the clays of that State, and published an extensive paper, calling the attention of capitalists to their value. The result has been a great expansion in the clay-working industries of Ohio, and to-day she ranks easily first among the clay manufacturing States of the Union. With no better or no more abundant clays than Indiana possesses, compare the following statistics of the leading clay-working industries in the two States in 1894:

	Ohio.	Annual Output.	Indiana.	Annual Output.
Paving Brick Factories	44	292,000,000	5	29,000,000
Sewer Pipe Factories	35	....	3	....
Stoneware Factories	37	24,350,000 gals.	11	600,000 gals.
C. C. and White Granite Ware Factories	31	....	1	....
Yellow Ware Factories	10	....	....	....

If Ohio can, as she has been doing, support on a paying basis the number of establishments given above, there is surely room for many more in Indiana.

The rapid growth, since 1890, in the clay industries of southwestern Indiana is due mainly to two causes, viz., the growing use of vitrified brick for street paving purposes, and the discovery of the great value of shale or laminated clay for making many of the grosser forms of clay wares.

Those clay industries already in existence in the coal-bearing counties may be grouped according to the kinds of wares they manufacture into the following classes:

1. The manufacture of paving material.
2. The manufacture of sewer pipe and hollow goods.
3. The manufacture of refractory material.
4. The manufacture of stoneware and pottery.
5. The manufacture of pressed front brick.
6. The manufacture of ordinary building brick and drain tile.

Each of these will be taken up and mention made of the processes involved, and such statistics will also be given in tabular form as could be obtained from the owners of the factories.

THE MANUFACTURE OF PAVING MATERIAL.

CHOICE OF CLAYS.—The two most valuable properties which a paving brick must possess are those of *vitrifaction*, or the power to withstand the absorption of water; and *toughness*, or the ability to withstand abrasion and wear. Parties who are thinking of erecting a plant for the making of pavers must choose a clay, which, when properly burned will possess in a high degree the above properties, else their money will be wasted in a worse than useless project.

Among the clays found in Indiana and mentioned in the previous chapter are many which are undoubtedly suitable for the making of paving material; yet before a plant be located at any deposit, full tests should be made, and the clay found therein proven to be refractory enough to stand up under the heat required to bring about vitrifaction, and yet to contain fluxes sufficient to cause vitrifaction to begin at a temperature considerably below that at which softening and loss of shape takes place. The only fully reliable test which can be made is the taking of a large quantity of the clay to some factory and there making it into brick and burning them under conditions as nearly as possible like those which will be present after the plant is erected. Such a test is far more valuable than the one commonly in vogue of sending a keg or two of the clay to some dealer in brick machinery, and having a dozen or twenty brick made therefrom. Such brick show only the *best products obtainable* from the clay, and are no criterion of what it will do under the normal and average conditions existing in a large plant. *They are made to sell brick machinery*, and all possible precautions are taken to have each one absolutely without flaw.

While the average composition of the best clays for paving brick and other purposes is well known, too much reliance must not be placed upon the chemical analysis of a clay in question, and no plant should be erected with it as the sole existing test. It serves well as a preliminary test to determine the *possible* usefulness of the clay for the purposes wanted, as from it the refractoriness can be readily judged, but it is no criterion of the toughness and other essential properties which the burned product must possess.

The clays found in western and southwestern Indiana which are suitable for making paving brick may be conveniently grouped under the following heads:

1. Carboniferous shales.
2. The more plastic under-clays of the coal seams.
3. Recent sedimentary clays of the river bottoms.

The question naturally arises, which of these is best suited for the purpose in hand? This can best be answered from the experiences of the past, and from the results of a long series of tests made under uniform conditions. When the paving brick industry was first started the larger portion of the bricks were made of the under or so-called "fire-clays" of the coal measures. These have been gradually supplanted by the shales, as actual experience has shown that the brick made from the latter are more lasting, wear more uniformly, and in general give far better satisfaction. Moreover the shales are far more abundant, more easily mined, and, while requiring the expenditure of more power to prepare them for use, are more easily vitrified than the under-clays.

No facilities being at hand for the proper testing of a large number of clays in order to prove the relative value for vitrified brick or the different kinds of materials mentioned above, I have availed myself of the results of a series of tests made by Prof. Edward Orton, Jr., at the State University of Ohio, on clays of the same nature from that State. These results were first published in the seventh volume of the Ohio Geological Survey, and afterwards, in a modified form, in "The Clay Worker" for July, 1895. From the latter publication the following extract is taken:

"The shales, or bricks whose chief component is shale, and whose color is red or dark, were grouped together and were represented by 23 samples. Fifteen varieties of fire-clay bricks, or those in which fire-clay is the largest constituent, and whose color is light, were grouped together. Four varieties of shale and fire-clay mixtures, in about equal proportions, were grouped together, and three varieties, composed of Ohio River sedimentary clays exclusively, constitute the last class. The average results of the tests of these four classes were as follows:

	No. of Samples.	Absorption.	Rattling.	Crushing sq. Inch.	Rank.
Shales	23	1.17	17 61	7,307	1
Fire-clay	15	1.62	17.32	6,876	2
Mixture	4	1.44	18.72	5,788	3
River clay	3	1.36	19.02	4,605	4

"In this table the shales have the advantage over their competitors, showing the first rank in absorption and crushing and a close second in rattling. The fire-clays are indicated as being slightly tougher than the shales, but considerably more porous. Also, the same tendency is again more strikingly illustrated in the table of bricks having the highest average excellence in the test. Taking the ten highest averages, represented by sixteen factories, it is found that thirteen are shale bricks, against three fire-clay bricks, showing that the best material of the State is 80 per cent. of it made of shale clay."

This series of tests, taken in connection with the experience of the past, proves conclusively that the shales are the best suited of the three classes of materials mentioned for the making of high grade paving brick.

LOCATING THE PLANT.—Other conditions besides the quality of the clay must be taken into consideration in choosing the site for the location of a paving brick or other clay factory. Among the most important of these are the quantity of clay, the amount of labor necessary to secure it and its nearness to fuel, railway facilities and markets for the manufactured product.

The quantity of clay used in a large paving brick factory in the course of a single year is much greater than is usually supposed. Taking into consideration the shrinkage in burning, each thousand brick of ordinary size, 2½x4x8½ inches, will require an average of 2½ cubic yards of clay; and standard paving blocks, 9x3x4 inches, will require one-third as much more. If the clay be 10 feet in thickness and 40,000 brick of ordinary size be made each day, about 1⅔ acres of the clay will be used each year. If block are made, about 2⅓ acres will be used. The quantity of clay available must, therefore, be carefully determined before the site of the factory is chosen.

The question of stripping becomes an important one in the securing of large amounts of clay, and its cost must always be considered in choosing a site for a plant. Many deposits of shale and fire-clay, otherwise valuable, are rendered comparatively worthless by the great amount of material overlying them. In some cases much of this material can be mixed with that of the main deposit without injury to the product. This should not be done, however, until numerous tests have proven beyond doubt its suitability for the purpose.

Where the number of factories is large and competition causes the output to be sold at a close margin the cost of fuel becomes an important factor in the making of clay products. This should always be considered, and other things equal, the plant located as near as possible to a cheap and practically inexhaustible fuel supply. In these days of protracted drouths the future water supply is another factor to be considered, for large quantities are used for steam purposes and for moistening the clay in the wet pan or pug mill.

The question of transportation is also a most important one in the choosing of a site for a clay factory. If possible the location should be such that first-class railway facilities can be readily obtained, and side tracks laid into the yard. The finished product can then be loaded directly into the cars without preliminary hauling in wagons. Other conveniences, however, should not be sacrificed to gain such railway facilities. It is much better to locate the plant in close proximity to the supply of clay and then build a single switch to it than to erect it by the main line of a railway a mile or two from the deposit. The latter plan has, unfortunately, been followed by three of the five factories in this State, necessitating much expense in the hauling or shipping of the raw material. Where possible it is better to locate close to the junction point of two or more railways. This eliminates largely the chance of an arbitrary advance in shipping rates, and provides direct communication with a greater number of markets.

Those paving brick factories which are located near cities of sufficient size to use brick for paving purposes have many advantages. If their output is of such a quality as to meet all requirements it can be laid down at a good profit in such a home market at a less cost than any outside competitor can furnish it after paying freight rates. In addition to this saving of transportation there is always a sale in such a city for the second grade brick for use in sidewalks, gutters, foundations, etc. From 10 to 25 per cent. of the total output of the average factory is composed of such "seconds." These are soft brick or those overburnt, cracked or twisted in burning. In the course of a year they amount to several hundred thousands, perhaps millions, and unless sold for some price accumulate until they become a nuisance in the yard. All sums which they bring may be counted as clear gain, and the cost of production of those unsold must be added to the debit side of the year's account.

Preparation of Clays.—But few clays are found in their natural state in such a condition that they can be taken directly from the deposit where they lie to the machine which shapes them into the unburned product. Almost all have to undergo some process of preparation in order that they may be reduced to a fine-grained, homogeneous and plastic mass. While this preparation is more necessary and thorough in the making of the finer grades of clay wares, the manufacturers of paving brick are beginning to realize that on account of the more rigid inspection and close competition of their products, more care must in the future be taken in the preliminary mixing and preparation of their clays. Especially is this true of such clays as contain foreign impurities, such as small nodules of iron carbonate or pebbles of lime. If not present in too great a quantity, these, when ground fine and intimately mixed with the mass of clay do little harm. But if allowed to pass into the body of the brick, or other ware, in coarse granules a large percentage of the finished product will be rendered wholly worthless. Where two or more clays are to be mixed together the mixing must be thoroughly and uniformly accomplished, else the toughness and general structure of the brick will be greatly impaired.

The quality of almost all clays is greatly improved by weathering. While the amount of material used in a paving brick factory is so large that such a procedure, in part, becomes impracticable, yet if the conditions are such that large quantities of the clay can be gotten out in summer and allowed to remain exposed to the winter's rains and frosts a tougher and better grade product will invariably result therefrom.

Although both shales and fire-clays are sedimentary deposits, their natural plasticity has been largely destroyed by the changes which they have undergone subsequent to their deposition. This plasticity can be restored only by grinding and kneading with water. Where large amounts of the clay have to be used, this grinding is almost universally accomplished by means of a machine called a "dry pan." Experience has proven that for the making of paving brick a dry pan nine feet in diameter, supported by an iron frame, and having the rims of the inner wheels or mullers from 10 to 12 inches wide, is the most suitable. With such a machine dry shale sufficient in quantity to make from 30,000 to 35,000 ordinary sized paving brick can be readily ground in ten hours. Where the shale or clay is wet or very plastic, or where the same or a greater number of the larger paving blocks are desired, two dry pans have to be used. These are set side by side, and in the larger and more modern factories in Ohio and Illinois have the clay delivered to them on an inclined chute. Such an arrangement is a great labor saver, as both pans can be tended by one man instead of requiring a half dozen or more, as in the older factories.

A part of the bottom of the dry pan is made of iron plates, with openings varying from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch in diameter. Through these the ground clay passes and is caught and elevated, and then dumped onto screens. Through these screens the particles of clay, of sufficient fineness to enter the substance of the brick, pass to the wet pan or pug-mill, while those too coarse for such a purpose are returned to the dry pan and reground. The kinds of screens used are many. Those known as fixed inclined, or gravity, screens are best suited for use in tall buildings, as they are simple and cheap, and require no power to operate them. For low buildings some style of vibrating screen is the simplest, cheapest and most saving of power. Rotary screens, while capable of performing much work, are wasteful of power and are very liable to get out of order.

The most important preparatory process through which clays are put is the tempering, or mixing with water, in order to develop sufficient plasticity for making them into the product desired. In the manufacture of paving brick the clay is most commonly tempered in pug mills. These are much cheaper and less cumbersome than wet pans, but the latter give far better results, as by them the particles of clay are not only *mixed* with those of the water, but are *ground* into intimate contact with them. The wet pan is also more suitable for mixing clays of different kinds, as a pug mill merely stirs their particles together without bringing them into close contact. However, these advantages are commonly overlooked, and the cheapness and simplicity of the pug mill, coupled with the fact that it requires less attention, leads to its more common use.

If possible, some sort of a storage bin should intervene between the screen and the pug mill, and above the latter. This will secure a more regular flow of clay into the mill, and thereby render its work more uniform and efficient. Difficulty will very likely be experienced, however, in getting the ground clay to run freely from the storage bin, as it will have a strong tendency to bank up and clog the openings. The use of warm water in tempering, especially in winter, will be found to add much to the ease with which the clays may be worked, and will at the same time improve the quality of the finished product.

The processes of preparation thus briefly described are not limited to the paving brick industry, but are practically the same in all factories using indurated clays, - whether for vitrified, refractory, or other products.

Making of Brick.—Paving brick are now almost universally made by what is known as the "stiff-mud" process. In this process the ground clay is moistened just enough to render it plastic without becoming soft and pasty. The brick formed from it, on leaving the machine, are firm enough to be handled and piled several courses high without breaking or losing their shape.

Two types of machines are used in making stiff mud brick. These are called, respectively, plunger machines and auger machines. In the former the tempered clay is pushed into a closed space or press chamber and then forced out through the die by means of a piston or plunger, which is operated intermittently by steam pressure. This style of machine is much less used than the auger for several reasons, chief among which are: (a) Numerous defects in the brick caused by bubbles of air which have passed with the clay into the press chamber, and, finding no means of escape, have been forced into the body of the brick and caused therein voids or cavities which weaken its strength; (b) the intermittent nature of the flow of clay which prevents the use of automatic machinery in handling the output; (c) the necessary dividing of the steam power of the engine in order to furnish the pressure necessary to operate the piston; (d) the cost of the plunger machine, which is usually considerably more than that of the auger.

The auger machine consists of a horizontal closed tube or cylinder with a cone shaped front end. The clay is admitted on top of the rear end of this tube, and is pushed forward much in the same manner as the meat in a sausage mill, by a set of blades or knives which are arranged spirally about an inner, revolving, horizontal shaft. These blades both cut and pug the clay, and carry it forward to the auger, or screw, working in the cone shaped portion of the machine. This auger is a solid iron screw with a single or double thread. Gathering up the clay it forces it from the larger to the smaller end of the cone, thereby compressing it greatly and causing it to issue through the die at the front opening in a steady and continuous stream or bar. This may be 4½x9 inches in size, and is then cut off in sections 2½ inches thick into "side-cut" brick; or it may be 2½x4½ inches in dimensions, when it is cut into sections 9 inches long, producing "end-cut" brick. The cutting of the bar of clay into sections of the proper dimensions is effected by wires attached to a frame, which is operated either by hand or by automatic machinery.

Stiff mud brick, however made, are apt to have certain defects, some of which it is hard to avoid. The most common of these is a laminated condition of the inner portion of the brick. This is, for the most part, due to the outer portions of the bar of clay being retarded by friction against the sides of the die as it is forced through it by either plunger or auger, while the inner portion, exempt from such friction, moves more rapidly onward. These laminations are less frequent in large bars of clay than in small ones, as a smaller proportion of the clay is in contact with the die. Hence the side-cut machines produce fewer of them than the end cut. For this reason more of the former are used, especially in the making of paving brick from soft gritless shales or "soapstones," which have a stronger tendency toward lamination than the harder, more non-plastic clays. All things considered, experience has proven that the side-cut auger machines are the best adapted to the making of paving brick from such raw materials as occur in southwestern Indiana. Three of the five factories now in operation are using such machines. Two of these began with end cut machines but found them unsuitable for working the shales. The latest improved side-cut auger machines, of which there are several patterns on the market, when supplied with automatic off-bearing belts, are capable of making 40,000 brick in 10 hours' time.

In most factories the brick are taken from the cutting table and passed through a repress machine before they are taken to the dryer. The value of this process is as yet a mooted question among paving brick makers. The prevailing opinion at present is that repressing improves the brick in smoothness and general appearance but not in structure The corners are rounded off and the rough sides caused by the passage of the cutting wires through the clay are obliterated. Two represses, each requiring the services of two men, are necessary to take care of the output of a single, side-cut, auger brick machine.

Drying the Brick.—After the brick have been given their shape on the cutting table or the repress, the next process in their manufacture is the driving off of the water which has been added to the clay to secure plasticity. The average daily output of a single modern side-cut machine contains almost 20 tons of this water. How to remove it quickly and cheaply by evaporation has been a question which has sorely puzzled paving brick makers in the past. Many methods have been devised but the one now most used, and which will most probably be connected with such paving brick plants as will be erected in the future, is known as the progressive or tunnel system.

By this system small iron or wooden cars, single or double decked, each holding from 350 to 500 of the undried block or brick, are pushed in at one end of a long, low tunnel or dry house, and by slow progression moved forward to the other end. This tunnel has close fitting doors at each end and three or four sets of double tracks. Beneath these, in the most modern dryers, are many thousand feet of radiating and coiled steam pipes. These are most abundant at the further end of the tunnel, where they are kept full of live steam at boiler pressure.

By the use of either tall wooden chimneys, or fans, currents of air are kept moving from the hot end of the dryer where the steam pipes are mostly located to the other end where the bricks are first entered. "By the time the air currents reach the rear end they have absorbed in passing through the great volumes of brick ahead, about all the vapor they are capable of retaining, consequently, the temperature is low, generally 80° to 100° F., and the air is filled with humidity, almost to the dew point. The new car-load of bricks in an atmosphere like this does not begin to dry at all, but it begins to warm through, till the individual bricks are as hot as the surrounding atmosphere. After a time the cars are shoved down the tunnel to make room for other cars in the rear. The first car now begins to find itself in an atmosphere a little warmer and not quite saturated with moisture. The water now begins to dry on the surface of the bricks, and as they have been previously brought to a warm steamy condition, the surface evaporation is constantly replaced by moisture from the inside. Hence, there is no tendency for the outside of the brick to contract faster than the inside and, therefore, no tendency to cracking or breaking. As the bricks proceed onward they yield up successive portions of their moisture and finally emerge from the hot end of the dryer ready for the kiln." *

In some progressive dryers hot air is used instead of steam, but the latter is the safer, more economical and more efficient drying agent. The daily output of an average factory can be dried ready for setting in the kilns in from 24 to 30 hours by the latest styles of progressive dryers. The cost of drying ranges from 20 to 35 cents per 1,000 bricks; 25 cents being the average cost at the Clinton Paving Brick Company's works.

Burning the Brick.—All other processes of clay manufacturing are subordinate in importance to that of the burning. Especially is this true of the manufacture of paving brick, where, upon the proper management

* Orton, Edw., Jr., Ohio Geol. Surv., VII, 169.

of the burning, more than upon the quality of the clay or its preparation, depends the degree of vitrifaction and toughness which the finished product will possess. For the most part the burning of vitrified products is carried on in down draft kilns. These are of several patterns, the most common of which is the round down draft from 25 to 28 feet in diameter and holding 28 to 30 thousand standard block, or 40 to 45 thousand ordinary sized brick. On account of the importance of this process, the following full and valuable account of the proper method of conducting it is taken from "The Clay Worker" for April, 1895. It was written by that noted authority on all subjects pertaining to clays, Prof. Edw. Orton, Jr., of Columbus, Ohio.

"The kiln may be supposed to be twenty-five feet in diameter, with ten fire holes of the inclined grate style, and the contents of the kiln are set twenty-five courses high. The fires are lighted at once, when the setters have finished their work and erected a single wicket in each door. The fires at first are very small, not over one-half bushel in cubic contents, and are at the bottom of the grate bars and in the foot of the bag. They are maintained at about this stage for the first twelve hours, when they are doubled in size. The temperature of the waste gases passing off in the stack at the end of twelve hours will be milk warm or a little more During the first three days the draft of the kiln is apt to be too feeble rather than too strong, so under usual conditions the stack has full chance, unobstructed by damper of any kind. The air supply entering the kiln during the first day is very large, as it has nearly the whole area of each fire hole. This space is gradually filled up as the size of the fires increase, so that the temperature of the gases passing into the kiln insensibly increases, hour by hour, as the air passages are diminished and the fires increased. During the first twenty-four hours the wickets, peep-holes and all openings except the fire holes should be finished up and daubed with mud and washed with clay-slip till air tight."

"During the second twenty-four hours the fires are again doubled, the increase being carefully distributed throughout the day. This will about half fill the fire holes, leaving the upper half of the openings free for air. The waste gases in the draft stack will feel much warmer at the end of the second day—probably from 140 degrees to 160 degrees, and they are so laden with water that they appear as clouds of steam if the outside air is cool. During the third day the fires are slightly increased, but not so as to more than two-thirds fill the fire holes. The waste gases rapidly increase in heat during the day, usually getting too hot for the bare hand, and the visible steam becomes less and less, generally disappearing before the end of twenty-four hours."

"The kiln has now passed through what is called in the trade the 'water-smoking' period. The water discharged is largely that which is free and merely left in the bricks from the dryers, though possibly some combined water has been expelled during the third day. The intention of the burner during this period is to subject the bricks to a liberal flow of air and gases, beginning at a low heat, and by the end of the third day attaining a temperature of 300 or 400 degrees. If this is done the last traces of free water will have been drawn out, and the kiln will be ready for raising 'fires.'"

"The fire holes are now filled up so that the air supply is nearly cut off, and what air does draw in over the top of the fire is hardly more than sufficient to consume the inflammable gases from in rear of the fires. Under this condition the fire holes soon become red, and soon after the bags and fire walls are seen to be red as well, and during the second half of the fourth day the bricks will become a dull red, easily seen at night and with difficulty by day. It is at this stage that the combined water is expelled, and the utmost caution and regularity are needed. The heat must be maintained and slightly increased, hour by hour, constantly aiming to cause the redness to travel downwards, course by course, without materially increasing the temperature of the top."

"The draft, if too strong, must be cut down, and the heat regulated by the size of the air inlets over the top of the fires. In cold weather steam will be seen for the second time during this day, but in warm weather the superheated vapor is absorbed into the atmosphere without condensation."

"The kiln should be gauged—that is, the distance from the top of the bricks to the top of the kiln should be carefully measured—during the fourth day, as soon as the bricks are hot enough to distinguish, or before. This figure should be noted down for future reference. During the fifth day the air supply will be nearly cut off, and the fire holes will be at their full heat. The temperature at the beginning of the day should be distinctly red on top and a barely visible red in the middle peep-hole on the twelfth course from the bottom. During the twenty-four hours the heat should be increased to a clear, bright cherry red on top, decreasing to a distinctly visible red on the bottom of the kiln, and on the draft stack. When this color is seen in the stack it is a sign that the necessary heat to expel the combined water from the clay has been attained from top to bottom, and that the bricks are now ready to take the finishing temperatures as fast as they can absorb them. The constant danger will be, during the fifth and subsequent days, that the top courses will become overheated for a few moments. If the burner is not constantly on the *qui vive*, after every firing, especially, the heat will become too great and the quality of the top courses will be damaged or ruined. If the work is skillfully done the top course will be still only a good, hard building brick at the close of the fifth day, while the bottom has arrived at the softest salmon stage."

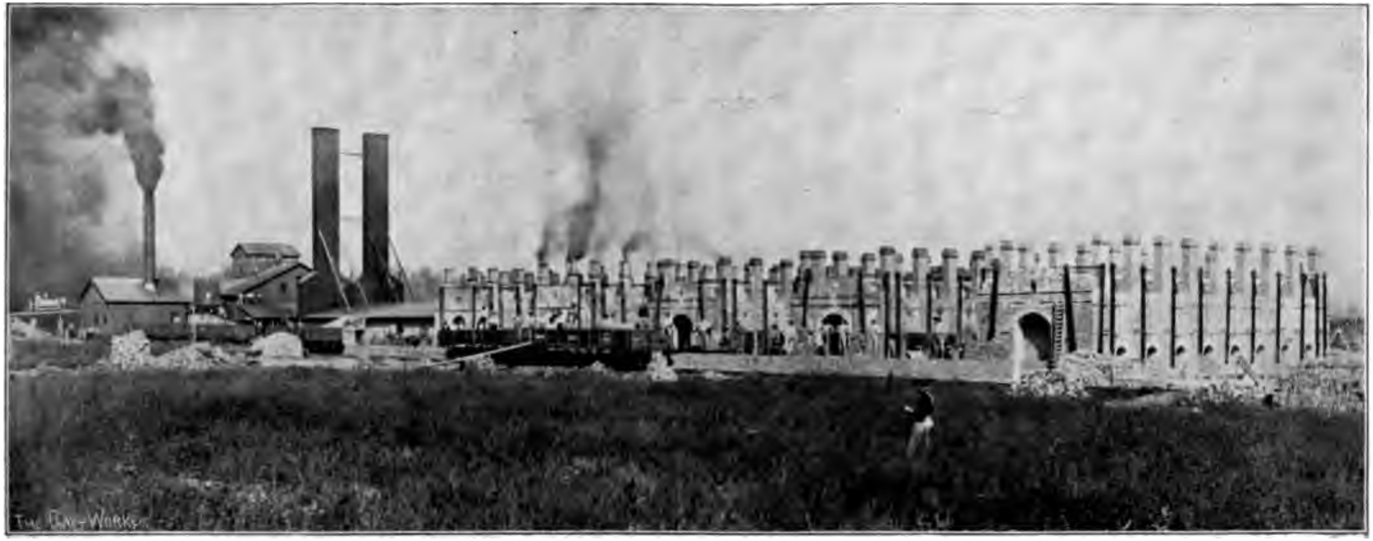
"On the sixth day the finishing process or 'high fire' begins. So far the rise in temperature has been comparatively regular and gradual. But after the gases have been expelled from the clay the danger of sudden changes in the heat is only that the highest limit may be exceeded; variations inside of that limit do no harm. The fires are managed much as before, the air supply being greater or less according to the heat needed for the moment. The top of the kiln becomes heated up to its practical limit of safety a few hours after the finishing process begins, and if the heat is still maintained without cessation the bricks will soon become spongy. If the heat be kept on for a few hours, until the top bricks begin to show signs of distress, and then allowed to cool off somewhat, together with an increase of draft, it is found that the top portions of the kiln will give out heat again, and, while cooling down themselves, they assist in bringing up the heat of the courses below them."

"By working the kiln as described and carrying wave after wave of heat from the top downwards the bottom of the kiln ought to become strongly red by the end of the sixth day, the top being as hard as is desired before this time. The gauge at this stage should show about five or six inches settle from the first figure, with a setting 25 courses high."

"The same method of firing during each succeeding 12 hours ought to show a further settle of two inches. By the end of the seventh day the settle will probably be 9 or 10 inches, and the trials taken from the top, middle and bottom will show the vitrification to be complete on top, fair in the middle and too soft on the bottom. Twelve hours more ought to bring the heat down to the bottom so that the settle shows 11 or 12 inches and the trial a hard building brick or poorly vitrified paver. The burn is ready to conclude at any time the burner sees fit, and he must now weigh in his mind the benefit and danger of each fire before putting it on. The conclusion of a burn under such conditions as have been described should not be later than the middle or end of the eighth day."

"In cooling off the practice varies. Experience has shown that the danger point in cooling vitrified clay ware is at a dark red or black heat. When the ware is very hot it can not be damaged by free admission of air, providing that it all enters through the fire holes and red-hot flues. The proper plan is to allow the kiln to cool down under full draft until it begins to look dark, then shut the dampers and cool as slowly as the kiln capacity will allow. Three to six days are allowed to round kilns."

"The slower the cooling the greater toughness is found in the product. The top course and the bricks immediately next the bags are always likely to be brittle in any case, as they are heated up and cooled down many times in the burn in accumulating the waves of heat by which the bottom courses are reached."



WORKS OF THE CLINTON PAVING BRICK CO., CLINTON, INDIANA.

COST OF PLANT.—The cost of a paving brick factory fitted up with modern machinery varies much, according to location, size, etc. In general it may be stated that the cost will be $1,000 for each one thousand daily capacity of output. This does not include the cost of land on which clay is situated, railway switches, nor the capital necessary to carry on the business before the returns begin to come in. Through the kindness of Mr. J. W. Robb, Secretary and Treasurer of the Clinton Paving and Building Brick Co., I have been furnished with the figures showing the exact cost of the plant of that company, which is one of the best and most modern in the State. These figures are as follows:

Five Eudaly kilns, capacity 125,000 each, including royalty of $1,000 for use of same	$14,782
Buildings, yards, etc	8,276
Machinery	7,766
Dryers (two "Ironclad" Progressive, complete)	9,144
Total	$39,938

The daily capacity of this plant if run full 10 hours is 40,000 paving brick, showing a very close approximation to the average cost as mentioned above. Further details concerning the machinery found in this plant are given in the following table of statistics of the paving brick industry in Indiana:

Statistics of Indiana Paving Brick Factories.

Name of Firm.	Location.	Began Oper't'g.	Capital Invested.	Product.	Kind of Machinery.	System of Drying.	Number and Kind of Kilns.	Total Kiln Capacity.	Number Hands Empl'd.	Average Daily Wages.	Annual Output, Millions	Value of Annual Output.
Clinton Paving and Building Brick Co.	Clinton, Vermillion County, Indiana.	1893	$50,000	Clinton pavers ((8½x4x2½ in.) and vitrified sewer brick.	One 9-foot dry pan. One 9-foot pug mill. One auger side-cut, Penfield No. 10 brick machine. Two Columbia represses.	Progressive ("Iron Clad"). Two 5-track tunnels.	Five square Eudaly down draft.	625,000 brick.	60	$1.42	8	$70,000
Wabash Clay Co.	Veedersburgh, Fountain County, Indiana.	1892	$90,000	"Poston" block (9x4x3 in.) and sidewalk brick.	Two 9-foot dry pans. One open-top pug mill. One augus side-cut. Bucyrus "Giant" brick machine. Three Raymond represses.	Progressive. One 6-track "Iron Clad" and one 8-track "Poston" tunnel.	Seventeen round, down draft.	510,000 block.	75	$1.35	8½	$110,000
Indiana Paving Brick Co.	Brazil, Clay County, Indiana.	1891	$40,000	Brazil block (9x4x2½ in.)	One 9-foot and one 7-foot dry pan. One open-top pug mill. One Wellsville auger side-cut machine. One Raymond and one Eagle repress.	Three dry floors; one heated by under-flues and two by steam. Total capacity, 240,000.	Eleven round, down draft.	350,000 block.	65	$1.35	6½	$70,000
Evansville Pressed Brick Co.	Evansville, Indiana.	1890	$50,000	Evansville pavers (8½x4x2½ in.)	Two 9-foot dry pans. Two horizontal pug mills. One Chambers auger end-cut machine.	Progressive. Two 4-track tunnels.	Seven square, down draft, of owner's design.	60 ,000 brick.	50	$1.50	5	$50,000
Hoosier Brick Co.	New Albany, Indiana.	1894	$40,000	Hoosier pavers (8½x4¼x2⅜ in.)		Progressive. Andrews system.	Two square, down draft.	500,000	25	$1.25	1	$10,000

WORKS OF THE WABASH CLAY CO., VEEDERSBURG, INDIANA.

COST OF MAKING PAVING BRICK.—This also varies much according to location and size of plant, price of labor, cost of fuel, etc. Where a factory is fitted up with modern machinery, has an output of 35,000 or more daily, and is situated by the side of the clay, fuel and water, so that these necessities can be obtained at a minimum price, the actual cost of making repressed paving brick and putting them on board the cars, is in the immediate neighborhood of $5.00 per thousand; of block, $5.50 per thousand. To this must be added the interest on capital invested, insurance, taxes, office expenses, salaries of salesmen and all other general expenses, which will bring the cost up to near $6.00 per thousand for the brick, and $6.50 for the block. The prices at which they now sell in Indiana are said by the makers to be $10.00 for the brick and $13.00 for the block on board the cars at the factories.

THE TESTING OF PAVING BRICK.—The question of the proper tests to which samples of the brick destined for paving streets shall be subjected is a most important one. Each city engineer has, up to the present, had his own opinions on this matter and has made his tests according to his own best judgment. As a result there is no recognized standard, nor official tests which can be taken as such. At the ninth (1895) meeting of the National Brick Manufacturers' Association a committee was appointed to report a standard method of making such tests. It is to be hoped that such a report will soon be made and a standard fixed which will become generally adopted by city engineers. This will enable manufacturers to test their own output, and if not up to the standard to devise means and methods of making it so. In the past they have had to trust, as it were, to luck in having their output adopted, as it was impossible to try to make it correspond with the many whimsical standards which were set up by city engineers.

As already stated the two essential qualities of a good paving brick are vitrifaction and toughness. Hence, the most important tests which can be made are those which will go to prove the presence of these qualities in proper degree. These are the absorption test and the abrasion or rattling test. As it may be some years before a set of standard tests is adopted, the following methods of making the absorption and rattling tests are given as ones which have been commended by experts.

For the absorption test, one whole and three half bricks of average hardness, which are free from kiln sand and which have not been subjected to the abrasion test, should be taken. These should be dried carefully over a register or in a radiator for twenty-four hours, at a temperature between 200 and 300 degrees. Each specimen should then be weighed accurately on scales which are graduated to at least $\frac{1}{4}$ of an ounce, and a record kept of their separate and combined weights. They should then be soaked in clear water for 24 hours, after which they should be wiped dry with a cloth and weighed again. The increase in weight denotes the amount of water absorbed. The sum of this should be reduced to a percentage of the dry weight, and this will be the per cent. of absorption. The maximum amount of this which is allowable in a paving brick is, as yet, an unsettled question. Some city engineers make two per cent. the limit. More fix the amount at one and one-half per cent. By far the greatest number of paving brick placed upon the market show a gain of less than one per cent., so that two per cent. is probably not far from the limit which it is best to allow. No brick should be condemned or endorsed on the absorption test alone, as such a test is an index only of the quality of vitrifaction, and gives no proof of the presence of the other qualities which the brick must possess.

For the abrasion test which is made to indicate the toughness of the pavers, a cask-shaped rattler with the staves and heads made of cast iron, or lined with steel or iron plates, should be provided. This should be 28 inches in diameter and 32 in length, and should have no shaft in the center, but be suspended by opposite corners.

The brick to be tested should each receive a special mark with a steel punch, and then be weighed carefully. Enough should be placed in the rattler to fill as nearly as possible 20 per cent. of its volume, and no foundry shot or other iron material should accompany them. If a sufficient number of brick to make out the 20 per cent. of the volume of the rattler aré not to be tested, standard paving brick from the most available source should be used as "fillers."

The rattler should then be turned for 40 minutes at the rate of 25 revolutions per minute. The brick are then taken out and weighed individually and collectively, and the percentage of loss by impact or abrasion is thus obtained.

The percentage of loss under the above method will vary much. The extremes will probably be about 5 and 25 per cent., and the average of 20 samples about 15 per cent. It will be found to be a severe test, but it will show with absolute certainty the *toughest* brick in the lot tested.

Other tests of paving brick which should be made are those showing the hardness and the cross-breaking or transverse strength. The former is easily determined by the use of the scale of hardness or scratching test, as the ability to scratch or to be scratched determines the relative hardness of any two substances. This scale is explained in all works on elementary physics, and is the one commonly in vogue with mineralogists. Its numbers run from one to ten, and certain well-known minerals are taken as types of each degree, talc or soapstone being No. 1; calcite No. 3, etc. Nos. 6 and 7, represented respectively by feldspar, a common constituent of granite rocks, and quartz, a very common mineral, are the two degrees of the scale which should be used comparatively in testing paving brick. No brick should be used for street purposes whose hardness is not 6 or above, while none showing a hardness above 7 are made. In making the test the inspector should be provided with pieces of feldspar and quartz, 2 x 4 inches, or larger in size, and also with an ordinary three-cornered file. The file should be drawn with considerable pressure over the narrow face or edge of the brick, and with the same amount of pressure over both the feldspar and the quartz, and observation made as to whether the depth of the cut in the brick is greater, less, or equal to that made in the minerals. If the scratch in the brick is less than that in the feldspar and deeper than that in the quartz the hardness of the brick is between 6 and 7, or the one desired; but if the scratch in the brick is plainer and deeper than that in the feldspar the brick is too soft and should be rejected.*

In making the transverse or cross-breaking test the brick should be placed edgewise on rounded knife edges, set 6 inches apart, and the load applied in the center by a rounded knife edge until the brick is broken. The transverse or tensile strength is then determined by the following formula:

$$f = \frac{3\ W\ l}{2\ b\ h^2}$$

in which

f = tensile strength in pounds per square inch.
W = breaking load in pounds.
l = length between the bearings.
b = breadth of brick.
h = height of brick.

The crushing test for brick was at one time largely used, but of late years has been considered of little value. "The crushing strength of a cube cut from a good paving brick is, say, 8,000 to 10,000 pounds per square inch, and if the pressure is applied on only a portion of the upper surface the strength is about twice as much. The surface of contact between a wheel having a 1½ inch tire, loaded with half a ton, is roughly about one square inch, which gives a pressure on the brick of only 1,000 pounds per square inch. Therefore there is no danger of the brick being crushed."† If made, the brick to be tested should be placed edgewise, and the edges should be previously ground smooth, else the real strength will not be obtained.

After the four tests of absorption, abrasion, hardness and transverse strength have been made it becomes necessary to average them, as in

---

* If doubt occurs as to the pressure exerted by the file being the same in each instance a piece of the brick can be used on the smooth surfaces of the pieces of the minerals, and *vice versa*. The harder bodies will scratch the softer.

†Baker I. O., Brick Pavements, p. 8.

most cases one sample will show the highest per cent. in one particular, and a second in another particular. The question then arises, what relative value or weight should be given to each test? The qualities of toughness and vitrifaction being most desired it is obvious that the tests of absorption and rattling should be rated higher than the other two in making out the average. Probably the best relative value which can be given each of the four in making out the final average is as follows:

Rattling	40 per cent.
Absorption	30 per cent.
Hardness	15 per cent.
Transverse strength	15 per cent.

The engineer in prescribing his specifications for bids should make known fully the manner in which each test shall be made, and the relative weight which shall be given each in computing the final average.

THE FORMATION OF BRICK PAVEMENTS.—While the making of brick streets is an industry entirely distinct from that of the manufacture of paving brick, the future of the latter industry depends wholly upon the successful wear of such streets and the satisfaction which they give to the general public.

Many brick pavements which have been put down in the past have proven costly investments, but a much larger number have proven entirely satisfactory both in comparative cost and wear. The failure of those unsatisfactory has been due to many causes. One of the most common of these has been the use of poor foundations. It has been long proven by experience that no matter how superior the wearing surface of the street may be, unless such surface is supported upon a firm and enduring foundation its lease of life will be short. Such a foundation is best made from hydraulic cement concrete, and its minimum thickness should be 6 inches. The manner of its proper formation has been well set forth in the specifications of the city engineer of St. Louis, Mo. These specifications are so plain and definite, both as to forming the concrete foundation and the choosing and laying of the brick, that that portion of them pertaining to these objects is here given as follows:

"SPECIFICATIONS FOR CONCRETE FOUNDATION."

"Upon the roadbed thus formed a sub-foundation of hydraulic cement concrete shall be laid to a uniform depth of 6 inches, which shall be prepared and applied as follows: The sand to be used in the mortar shall be clean, sharp, silicious river sand, free from loam or dirt, and before it is used all gravel, sticks and other foreign admixtures shall be removed by screening."

"The cement used shall be hydraulic cement, equal in all respects to the best Utica or Louisville cement. It shall be newly made, fine ground, and capable of withstanding a tensile strain of sixty (60) pounds per square inch of section when mixed pure and made into test bars and exposed thirty (30) minutes in air and twenty-four (24) hours or more in water. Cement in bags or packages not branded with the name of the maker will not be received. Cement in jute sacks will be rejected without test. Samples for testing shall be furnished in such manner and at such times as may be required. On all casks or packages accepted, such inspection marks will be placed as may be required, and the contractor shall carefully preserve these marks and not allow them to be imitated. The cement shall be kept under cover and dry until used, and any cement exposed to the weather after testing shall not be used. Cement may be re inspected at any time when the street commissioner shall so direct, and if not found to be of proper quality it shall be rejected. All rejected cement shall be at once removed from the line of work."

"The mortar shall be prepared from cement and sand, in the proportions of one part of cement to two parts of sand, by measurement. The sand and cement to be thoroughly mixed dry in proper boxes, after which a sufficient quantity of water shall be added to produce a paste of proper consistency, and the whole thoroughly worked with hoes or other tools. The mortar always to be mixed fresh before being applied to the broken stone."

"The concrete shall be made of broken limestone and hydraulic cement mortar, the stone to be broken so as to pass through a two and one-half (2½) inch ring in its largest dimensions. The stone shall be clean from all dust and dirt, and thoroughly wetted, and then mixed with mortar; the general proportion being one part of cement, two parts of sand, and five parts of stone. It shall be laid quickly and then rammed until the mortar flushes to the surface. No walking or driving over it shall be permitted when it is setting, and it shall be allowed to set for at least twelve (12) hours, and such additional length of time as may be directed by the Street Commissioner or his duly authorized agents, before the pavement is put down. All materials used in the construction of the pavement shall be brought on to the concrete only in barrows, or delivered on the concrete from the sidewalk."

"SPECIFICATIONS FOR WEARING SURFACE."

"Upon the foundation of concrete shall be laid a bed of coarse, sharp sand, free from gravel, loam or vegetable matter, and ...... inches in thickness when compacted to serve as a bed for the bricks. Upon this base of sand a pavement of the best quality of vitrified paving brick shall be laid. The bricks shall not be less than seven and one-half inches nor more than nine inches long, not less than .... inches nor more than three inches wide, not less than three and one-half inches nor more than four and one fourth inches deep, with rounded edges with a radius of three-eighths ($\frac{3}{8}$) of an inch. Said brick shall be of the kind known as "repressed" brick, and shall be repressed to the extent that the maximum amount of material is forced into them. They shall be free from lime, sand and other material, except pure shale; they shall be as nearly uniform in every respect as possible; they shall be burned so as to secure the maximum hardness, so annealed as to reach the ultimate degree of toughness, and thoroughly vitrified so as to make a homogeneous mass."

"All paving brick must be homogeneous and compact in structure, free from lumps of uncrushed shale or from laminations caused by the process of manufacture, or fire cracks or checks of more than superficial character or extent. The brick to be used shall be made from pure shale of quality equal to that found in Galesburg and Glen Carbon, in the State of Illinois, and Canton, in the State of Ohio. All bricks so distorted in burning or with such prominent kiln marks as to produce an uneven pavement, shall be rejected. All bricks shall be free from lime or magnesia and shall show no signs of cracking or spalling on remaining in water ninety-six hours."

"The bidders shall submit twenty-five samples of the brick they propose using. A portion of those bricks shall be subjected to such physical tests as the Board of Public Improvements shall deem necessary, and the remainder be retained as samples of the material to be furnished and used. Any brick which does not stand the tests satisfactorily will be rejected, and no bid contemplating the use of the rejected brick shall be entertained. Samples may be submitted by manufacturers, in which case the bidder proposing to use brick of such manufacture will not be required to submit samples. The quality of the brick furnished must conform to the samples presented by the manufacturers and kept in the office of the Street Commissioner."

"Such specimen brick shall be submitted to a test for one-half hour in the machine known as a "Rattler" with cast-iron bricks weighing six pounds each, making thirty revolutions per minute, and if the loss of weight by abrasion or impact during such test shall exceed fifteen per cent. of the original weight of the bricks tested, then the brick shall be rejected. The brick shall have a specific gravity of not less than two. They shall not absorb more than one and one-half per cent. of water when dried at 212 degrees Fahrenheit and immersed twenty-four hours in water."

"The Street Commissioner reserves the right to reject any and all brick which in his opinion do not conform to the above specifications."

"All brick may have a proper shrinkage but shall not differ materially in size from the accepted samples of the same make, nor shall they differ greatly in color from the natural color of the well-burned brick of its class and manufacture."

"No bats or broken brick shall be used except at the curbs, where nothing less than a half brick shall be used to break joints. The bricks to be laid in straight lines and all joints broken by a lap of at least two inches, to be set upon the sand in a perfectly upright manner as closely and compactly together as possible, and at right angles with the line of the curb, except at street intersections where they are to be laid as the Street Commissioner may direct."

"The pavement shall be thoroughly rammed two or three times, as may be directed by the Street Commissioner, with a paver's rammer weighing not less than seventy-five pounds, or a road-roller weighing not less than three nor more than six tons; and all the joints in the pavement shall be completely filled with .... and an additional layer of sand not less than one inch in depth shall be spread uniformly over the whole surface of the pavement."

THE PERFECT PAVEMENT.—The requirements which shall constitute a perfect pavement have been well summed up as follows:

First. Reasonableness in first cost.

Second. Low in cost of maintenance and easy to repair.

Third. Durability under traffic and reasonable freedom from noise and dust.

Fourth. Free from decay, waterproof and non-absorptive.

Fifth. Of low tractive resistance and furnishing a good foothold for horses.*

Suffice it to say that such a pavement has never as yet been constructed. The nearest approaches to it are those of vitrified brick, made from just such shales as are found in so great abundance in southwestern Indiana.

In order to gain some idea of the extent to which vitrified brick have been used for street paving purposes in Indiana, their durability and the general satisfaction which they give, a letter was sent to the city engineer of each city in the State where brick pavements are in use, and a blank was enclosed to be filled out and returned. Replies were received from all the engineers except those of the following places: Elkhart, Summitville, Dunkirk and Decatur. From these replies the following table has been compiled:

* Mead, Daniel W. Proc. Ninth Ann. Conv. Nat. Brick Manf's. Ass'n., 1895, 34.

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana.

Name of City.	No. of Miles of Brick Pavements in Use.	Kind, and Thickness of Foundations.	Average Cost per Lineal Foot Each Side of Street.	Average Width of Street.	Total Number of Brick Used to Date.	Total No. of Block Used to Date.	Total Cost of Pavements.	Places of Manufacture of Brick.
Alexandria.	1,900 feet.	Broken stone; 8 inches.	$5.50	55 feet.	520,000		$22,000	Minerva, Ohio.
Anderson.	4¾ miles.	Gravel; 10 inches.	$4.50	40 feet.	7,000,000		$230,000	Canton, Ohio (6,000,000). Minerva Ohio, (1,000,000).
Elwood.	2½ miles.	Broken stone; 10 inches on 1 mile. Gravel; 10 inches on remainder.	$3.96 for vitrified brick; $2.40 for common brick.	35 feet.	1,050,000 common brick; 220,000 vitrified brick.		$105,000	Canton, Ohio (2,100,000 shale brick). Malvern, Ohio (150,000 fire-clay brick). Elwood, Ind. (1,050,000 common brick).
Evansville.	18 miles.	Concrete; 6 inches on 13 miles. Broken rock and two courses of brick, making 8 inches, on 5 miles.	$3.85	38 feet.	13,750,000	4,000,000	$701,000	New Cumberland, W Va. (3,000,000). Middleport, Ohio (1,000,000). Decatur, Ill. (1,500,000). Ironton, Ohio (1,000,000). Evansville, Ind. (7,250,000).
Frankfort.	11 squares.	Concrete; 8 inches. Sand, 1 inch.	$4.72			1,050,000	$40,000	
Franklin.	¾ miles.	Concrete; 6 inches.	$4.10	28 feet.			$28,700	
Ft. Wayne.	4.57 miles, or 88,788 square yards.	Broken stone; 6 inches on 66,096 square yards. Concrete; 6 inches on 16,782 square yards. Concrete; 8 inches on 5,910 square yards.	$3.15	33 feet.	4,089,000	935,000	$157,838	Bucyrus, Ohio (1,550,904 shale brick). Canton, Ohio (1,830,400 shale brick). Massillon, Ohio (117,646 fire-clay brick). New Cumberland, W. Va. (581 000 fire-clay brick).

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana.

Name of City.	Places of Manufacture of Block.	Cost of Brick per 1,000.	Cost of Block per 1,000.	Cost of Brick and Block Made in Indiana.	Cost of Brick and Block Made Outside of Indiana.	Durability of and Satisfaction Given by Brick Pavements.	General Remarks.
Alexandria.		$13.00			$6,760	Not used sufficiently to prove durability; satisfaction good.	Probably 15 squares will be put down next season.
Anderson.		$12.00			$84,000	Pavements constructed in 1892 93 show very little signs of wear; satisfaction good.	Probably 2,000,000 paving brick will be used in 1896.
Elwood.		Vitrified brick, $13.00; common brick, $5.		$5,250	$30,000	Canton brick where foundation has not been disturbed have given entire satisfaction. Fire-clay brick crumble rapidly after hard outer shell has worn through.	Common brick pavements last 5 years without repairs as compared with gravel at almost same price, with constant repairs.
Evansville.	Middleport, Ohio (2,000,000). Ironton, Ohio (2,000,000).	$10.00	$13.50	$72,500	$119,000	All shale brick are wearing well under heavy traffic. West Virginia fire-brick are showing signs of disintegration under same conditions.	Seventy-five to 100 squares of brick pavement will be put down in 1896. Two million vitrified brick have in addition already been used in alleys.
Frankfort.	Veedersburg, Ind.		$13.00	$13,650		Just constructed.	
Franklin.	Veedersburg, Ind.		$14.00			Good as new after two years' wear; satisfaction excellent.	Twelve squares will be put down in 1896.
Ft. Wayne.	New Cumberland, W. Va. 935,000 fire clay block.	$11.50	$18.00		$62,853	Pavements laid in 1891 in fair condition; satisfaction good.	10,272 square yards of vitrified brick have been laid in alleys to date.

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana—Continued.

Name of City.	No. of Miles of Brick Pavements in Use.	Kind, and Thickness of Foundations.	Average Cost per Lineal Foot Each Side of Street.	Average Width of Street.	Total Number of Brick Used to Date.	Total No. of Block Used to Date.	Total Cost of Pavements.	Places of Manufacture of Brick.
Gas City.	4,977 feet. (lineal.)	Crushed stone; 6 inches. Sand; 2 inches.	$6.22	50 feet.		1,326,500	$61,968	
Huntington.	2 miles.	Broken stone; 8 inches.	$3.70	36 feet.		2,000,000	$72,182	
Indianapolis.	14.6 miles.	Concrete; 6 inches.	$3.72½ including curbing.	35 feet.			$744,432	
Jonesborough.	4,550 lineal feet.	Coarse gravel, 10 inches.	$3.75	50 feet.		1,200,000	$33,000	
Kokomo.	$\frac{4}{10}$ miles.	Concrete, 6 inches.	$5.34	36 feet.		388,810	$10,890	
Lafayette.	1 $\frac{53}{100}$ miles.	Gravel, 6 inches; sand, 2 inches; hard brick, flat, 2 inches; sand, 1½ inches.	$4.18	39 feet.	1,776,000		$68,996	Veedersburg, Ind.; Clinton, Ind.; Canton, Ohio; Bloomington, Ill.; Galesburg, Ill.
Laporte.	15,393 square yards.	Broken stone, 6 inches; sand, 2 inches.	$5.48	39 feet.	877,500		$22,012	Canton, Ohio.
Logansport.	$\frac{83}{100}$ miles.	Broken stone, 8 inches on 4 squares; concrete, 8 inches on 5 squares.	$3.60 with broken stone foundation; $4.87 with concrete foundation.	50 feet.		753,000	$27,586	

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana—Continued

Name of City.	Places of Manufacture of Block.	Cost of Brick per 1,000.	Cost of Block per 1,000.	Cost of Brick and Block Made in Indiana.	Cost of Brick and Block Made Outside of Indiana.	Durability of and Satisfaction Given by Brick Pavements.	General Remarks.
Gas City.	Logan, Ohio.		$18.00		$23,877	Satisfaction excellent.	
Huntington.	Hocking Valley, Ohio.		$20.00		$40,000	Good.	Probably 10 squares will be laid with vitrified brick in 1896.
Indianapolis.						Those laid last two years are fairly good; those laid prior are poor.	
Jonesborough.	Canton, Ohio.		$13		$15,600	Constructed in 1895	
Kokomo.	Veedersburg, Ind.		$13	$5,044		Just completed.	Probably 6 squares will be paved with brick in 1896.
Lafayette.		$13.62		$8,000	$16,089	Durability of the brick from Bloomington and Galesburg, only fair; the others, satisfactory.	
Laporte.		$15			$13,175	In use but one year; satisfaction good.	Seven squares will probably be put down in 1896.
Logansport.	Veedersburg, Ind.		$16	$12,048		Good.	Two rows of common red tile are placed under the foundation and connected with sewers. This investment pays better than any other portion of the construction. Concrete foundation is preferable.

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana—Continued.

Name of City.	No. of Miles of Brick Pavements in Use.	Kind and Thickness of Foundations.	Average Cost per Lineal Foot Each Side of Street.	Average Width of Street.	Total Number of Brick Used to Date.	Total No. of Block Used to Date.	Total Cost of Pavements.	Places of Manufacture of Brick.
Marion.	3 1/8 miles.	Macadam, 8 inches; sand 2 inches.	$3.50	30 feet.	2,283,600	795,000	$115,605	Canton, Ohio.
Michigan City.	3.16 miles.	1 inch pine board, and 5 inches crushed stone.	$1.37	23 feet.	2,147,558	224,000	$62,401	Michigan City (1,352,000 hard brick); Brazil, Ind., 403,98) vitrified brick; Clinton, Ind. (391,220).
Montpelier.	1,972 linear feet.	Concrete; 6 inches.	$2.83	30 feet.		243,000	$11,206	
New Albany.	1/4 mile.	Concrete; 6 inches. Sand: 2 inches.	$6.55, including curb and sidewalk.	60 feet.	412,750		$14,385	New Cumberland, W. Va.
Noblesville.	1 1/3 miles.	Gravel; 12 inches.	$4	40 feet.		900,000	$45,000	
Peru.	7,700 square yards.	"Paved bowlders"; 6 inches. Sand; 1½ inches.				369,600	$8,131	
Richmond.	1 1/5 mile.	Broken stone: 6 inches. Sand; 2 inches.	$6	45 feet.	3,000,000	75,000	$75,000	Canton, Ohio (2,500,000). Athens, Ohio (400,000). Trumble, Ohio (100,'00).
Seymour.	1,070 linear feet.	Gravel, concrete; 6 inches. Sand; 2 inches.	$4.48, including curbing of oolitic limestone.	54 feet.		320,000	$9,587	

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana—Continued.

Name of City.	Places of Manufacture of Block.	Cost of Brick per 1,000.	Cost of Block per 1,000.	Cost of Brick and Block Made in Indiana.	Cost of Brick and Block Made Outside of Indiana.	Durability of and Satisfaction Given by Brick Pavements.	General Remarks.
Marion.	Veedersburg, Ind.	$15.50	$15.00	$11,925	$35,395	The first brick street was built six years ago; has never cost a cent for repairs, and is in good condition at this time. No complaint except as to noise.	Sixteen squares will be put down in 1896.
Michigan City.	Veedersburg, Ind.	$11.00	$16.50	$24,600		General satisfaction given by the *vitrified brick* and block.	
Montpelier.	Canton, Ohio.		$14.00		$3,402	Put down in 1895.	Ten thousand square yards of brick pavement will probably be put down in 1896.
New Albany.		$13.00			$5,365	Excellent.	
Noblesville.	Canton, Ohio (572,000). Zanesville, Ohio (328,000).		$16.50		$14,850	Good.	
Peru.	Veedersburg, Ind.		$13.00	$4,803		Satisfaction good.	
Richmond.	Haydenville, Ohio. (75,000).	$16.00	$18.50		$50,000	General satisfaction, poor. Not the fault of the brick, but the bad manner in which the work was done.	
Seymour.	Athens, Ohio.		$12.50		$4,000	Constructed in 1895.	Seven squares will be put down in 1896.

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana—Continued.

NAME OF CITY.	No. of Miles of Brick Pavements in Use.	Kind, and Thickness of Foundations.	Average Cost per Lineal Foot Each Side of Street.	Average Width of Street.	Total Number of Brick Used to Date.	Total No. of Block Used to Date.	Total Cost of Pavements.	Places of Manufacture of Brick.
South Bend.	4 miles.	Gravel; 6 inches; thoroughly rolled.	$2 08	39½ feet.	5,500,000	3[illegible]8,600	$87,904	South Bend (2,750,000). Canton and Malvern, Ohio (2,000,000). Zanesville, Ohio (750,000).
Terre Haute.	3.53 miles.	Broken stone; 8 inches; on 2.28 miles. Concrete; 5 inches; on 1.25 miles.	$5.71 on broken stone.	42 feet.	5,635,380	119,080	$236,284	Canton, Ohio (3,770,000). Clinton, Ind. (690,600). Veedersburg, Ind. (1,274,200).
Tipton.	2.71 miles.	Gravel; 10 inches.	$4.84 for vitrified brick. $2.18 for common brick.	33 feet.	651,000 vitrified brick; 1,430,000 common brick.	519,000	$82,274	Canton, Ohio: vitrified brick. Tipton, Ind.: common brick.
Washington.	2 miles.	Concrete; 6 inches. Sand; 2 inches.	$390 including curbing.	34 feet.	640,000	1,520,800	$87,182	Evansville, Ind.
Total outside of Indianapolis.							$2,416,131	

Statistics Concerning the Use of Vitrified Brick for Street Paving in Indiana—Continued.

Name of City.	Places of Manufacture of Block.	Cost of Brick per 1,000.	Cost of Block per 1,000.	Cost of Brick and Block Made in Indiana.	Cost of Brick and Block Made Outside of Indiana.	Durability of and Satisfaction Given by Brick Pavements.	General Remarks.
South Bend.	Carrollton, Ohio.	$12	$14	$33,000	$37,000	From indications of pavements in use five years, they are good for twenty years on the streets having the most heavy traffic. South Bend and Canton brick give good satisfaction. The "fire clay" brick do not seem to stand so well.	The South Bend bricks are made from a plastic blue clay (calcareous), which burns buff, or, when thoroughly vitrified, blue. It is entirely free from pebbles and must have been deposited in still water.
Terre Haute.	Veedersburg, Ind.	$15	$20.50	$31,875	$56,550	Good.	
Tipton.	Canton, Ohio.	$10, vitrified brick. $6, common brick.	$13	$8,580	$12 738	Vitrified brick, good. Common brick, all right, if properly burned, but some which were too soft have been used.	Twenty-five squares will probably be paved in 1896.
Washington.	Athens, Ohio.	$10	$13	$6,400	$19,770	The pavements from brick are wearing well. The brick being a little too hard the edges and corners are somewhat rounded by eighteen months' use. The block pavements were constructed in 1895.	Twenty squares will probably be paved with brick in 1896.
Total outside of Indianapolis.				$237,675	$647,022		

When it is remembered that the use of brick pavements did not begin until 1890, it will be seen that they have come into popular favor in our State in a very short time. Those made from shale brick, when the foundation has been properly constructed, have everywhere given good satisfaction; while the durability of those from "fire-clay" brick is generally reported as poor. From the foregoing table it may be seen that in Indiana, outside of Indianapolis,* $2,416,131 have been expended in brick pavements. Of this large sum the brick have cost $884,697. But $237,675 have been spent for material made in Indiana, while $647,022 have gone to Ohio, West Virginia and Illinois for brick, every one of which could have been made in Indiana, and laid down at a fair profit in the cities using them for a less price than they were shipped in from other States.

THE MANUFACTURE OF SEWER PIPE AND HOLLOW GOODS.

Under this head is included the making of sewer pipe, fire-clay chimney tops and flue linings, hollow building brick and vitrified drain tiles. In one or two factories all of these wares are made, but in most places only special lines are produced. All of these products except the chimney tops and flue linings are vitrified in the making; the two exceptions are burned at a lower temperature, and are not salt glazed as are the others.

The clays used are the same as for making paving brick, *i. e.*, under-clays or shales, but in this State more of the products are as yet made from the former. Shale is used by the Chicago Sewer Pipe Co., of Brazil, and the Terre Haute Hollow Brick and Pipe Co., and in both places the wares are of superior grade, and there is less loss in drying and burning than in those factories which use an under-clay exclusively.

The preparation of the clays for these goods is made by essentially the same processes as those used in the making of paving brick. The wet pan is most used in tempering, and the latter process is therefore more thorough than can be accomplished in a pug mill.

A machine known as the sewer-pipe press is the one almost universally used in the making of pipe and hollow goods. It is a modification of the "plunger" brick machine previously mentioned, and consists of two cylinders placed upright one above the other, and separated by a heavy cast iron frame, to which the cylinder heads are bolted. The upper or steam cylinder is usually 40 inches in diameter, and the lower or clay cylinder, 18 inches. The piston rod is made either single or triple, and is continuous from the clay piston to the steam piston. The clay piston

*I was unable to secure complete statistics at the office of the City Engineer of Indianapolis.

is a cast iron head which can be replaced easily when worn. Steam pressure is used in operating the machine, and is controlled by a lever from the level of the working platform.

Seven or eight men constitute the "press gang" necessary to operate the machine and remove the pipe as fast as made to the dry floors. The size of the sewer pipe varies from 4 inches in diameter to 36 inches, or even larger, but the sizes most used range from 8 to 16 inches. As fast as made they are cut to the desired length, and each is set upright on a wooden pallet of appropriate size. These pallets are then placed on trucks and taken to the dry floors

The drying of sewer pipe is almost wholly accomplished on what is known as "sewer pipe floors,' by means of steam. These floors vary much in size, according to the output of the factory, and are usually three or four in number, one above another. They are slatted or open and the steam pipes are arranged beneath the lower one or two. The largest pipes are placed on the lower floor. Exhaust steam from the engine and presses is used by day, and direct steam by night. The process is necessarily a slow one else many of the pipe would crack. Those made from shale are much less apt to crack while drying than those from fire-clay.

Sewer pipe are burned, for the most part, in round down-draft kilns, and the process is essentially the same as that described under paving brick, except that much less time is required, owing to the thin sections of clay to be vitrified. For shale pipe three days is usually sufficient, and for those made of fire-clay, three and one-half to four. The pipe are usually glazed by the addition of small quantities of packing-house salt to the fuel during the last stages of burning. This glazing is done to secure smoothness of surface and a dark color. The color makes little or no difference in the quality of the pipe, but they are largely graded according to it. Prof. Orton has well said: "The system of grading sewer pipe is unnecessarily severe. For any ordinary use, the seconds are as good as the firsts; it is not the consumer who profits by the severity of selection; it is the middle men or retailers who buy the seconds at low rates and work them off on the public as first-class goods, which for any matter of service and utility they are."*

The making of hollow building brick or tile is rapidly assuming large proportions in western Indiana. Three large factories have been erected since 1890, in which these brick form the special output, and a fourth has added them to its former productions. These brick are plain sections of a square hollow bar. Their standard size is 8¼x8¼x16½ inches, with the hollow portion cross-webbed to give them additional strength. They can be made by either the auger or plunger brick machines, and

*Ohio Geol. Surv. VII, 214.

dried on dry floors or in progressive tunnel dryers. The advantages claimed for them over ordinary brick or stone for building purposes are as follows:

1. Cheapness, costing less than either brick or stone.
2. Being thoroughly vitrified they do not absorb any moisture, and always make a dry wall.
3. Being hollow they are more healthful for dwelling houses—warm in winter and cool in summer.
4. Make a stronger foundation, as each brick will stand a weight of more than 100,000 pounds.
5. As all ware is vitrified the walls will always keep clean, and will not become dingy as cut stone and brick usually do.

A handsome rock-faced tile for foundation work above ground is also made by several of the factories.

The making of pumps from clay has been carried on for 21 years by Weaver Bros., at Brazil, Indiana. The entire pump, except the handle, bolts and suckers, is made of vitrified fire-clay. These "stone" pumps are guaranteed to last for 10 years, and a number about Brazil have been in use for 21 years, and are none the worse for wear. They are fitted up and put in the well for $8 for the first 10 feet, and 25 cents for each additional foot.

The following table comprises the available statistics of the sewer pipe and hollow goods industries of Southwestern Indiana:

WORKS OF WEAVER BROS'. CLAY FACTORY, BRAZIL, IND.

WORKS OF EXCELSIOR CLAY CO., BRAZIL, IND.

Statistics of Sewer Pipe and Hollow Goods Industries of Southwestern Indiana.

Name of Firm.	Location.	Began Operation.	Invested Capital.	Kind of Products.	System of Drying.	Number, and Kind of Kilns.	Kind of Clay Used.	Number of Hands Employed.	Average Daily Wages.	Value of Annual Output.
Goucher, McAdoo & Co.	Brazil.	1894	$75,000	Sewer pipe, culvert pipe, fire proofing, flue linings, chimney tops, etc.	Sewer pipe floors, steam heated.	Twelve, round, down-draft.	Plastic under-clay.	100	$1.50	$90,000
Chicago Sewer Pipe Co.	Brazil.	1893	$50,000	Sewer pipe.	Sewer pipe floors, steam heated.	Eight, round, down-draft.	Shale and surface clay mixed.	40	$1.50	$60,000
Dee Sewer Pipe Co.	Mecca, Parke County.	1895	$50,000	Sewer pipe.	Sewer pipe floors, steam heated.	Four, round, down-draft.	Shale and surface clay.			$40,000
A. D. Clark.	Cannelton, Perry County.	1862	$15,000	Sewer pipe and stoneware.	Sewer pipe floors, steam heated.	Three, round, down-draft.	Plastic under-clay.	20	$1.25	$15,000
Brazil Brick and Pipe Co	Brazil.	1890	$50,000	Hollow building brick, vitrified drain tile and fire brick.	Sewer pipe floors, steam heated.	Seven, round, down-draft.	Plastic under-clay.	35	$1.50	$50,000
Excelsior Clay Works.	Brazil.	1895	$30,000	Hollow brick, vitrified drain tile, flue linings, etc.	Progressive tunnel, steam heated, 4 tracks.	Seven, round, down-draft.	Shale and under-clay.	50	$1.50	$30,000
Weaver Clay and Coal Co.	Brazil.	1872	$10,000	"Stone" pumps, vitrified drain tile, hollow brick, flue linings, door steps, etc.	Sewer pipe floors, steam heated.	Two round, down-draft, and one oven draft.	Plastic under-clay.	10	$1.50	$15,000
Terre Haute Brick and Pipe Co.	Terre Haute.	1895	$40,000	Hollow building brick, vitrified drain tile, and paving brick.	Progressive tunnel, steam heated, 6 tracks.	Six, round, down-draft.	Shale and plastic under-clay.	35	$1.50	$40,000
Total.			$320,000					290		$340,000

THE MANUFACTURE OF REFRACTORY MATERIAL.

The making of refractory material is carried on in but four factories in Indiana, and in two of these only as a side issue. Fire-brick, cupola linings, tiles for the floors of kilns and grate backs constitute the principal products made. Three of these factories derive their clay from the stratum which occupies quite an area in Parke and Vermillion counties, and which is fully described among the clays of the latter county. It is a white, semi-plastic under-clay of the coal measures and contains 98 per cent. of refractory material.

The dry pan is used in grinding the clay and the wet pan, or pug mill, in tempering it. The latter process is done more thoroughly than in the making of paving brick in order to develop as much as possible the property of plasticity.

The bricks are molded either by hand or on soft-mud machinery, the auger and plunger types of machines being wholly unsuited to their making. Those made on the soft mud machines are much rougher than the ones made by hand, and have to undergo the process of repressing. When first made they are too soft to bear handling and must be partially dried before being repressed. This drying is accomplished on a dry floor heated by under-flues. The moulding usually takes place in the afternoon and the repressing and setting in the kilns in the forenoon. By this system the bricks are dried from 12 to 24 hours.

Round down-draft kilns are used in the burning of refractory products, the process occupying about five days. Less care is taken in the burning than with any other kind of clay wares, as on account of the refractory nature of the material there is little or no danger of fluxing or overburning.

Within recent years the manufacture of fire-brick has been attempted by the dry-press process. The Huntingburg Dry Pressed Brick Company, of Huntingburg, Dubois County, is the only company which has thus attempted their making in Indiana, and that only on a small scale; but in Ohio, according to Orton, this process is being used successfully in one or two fire-brick factories. If the attempt proves successful it will revolutionize the making of refractory products, as they can be made more perfect in form and size, denser and stronger, and at a less cost by the dry-press process than by any other known.

The making of glass-pots and linings for glass-tanks, the highest and most technical part of the refractory clay industry, has not as yet been attempted from Indiana clays. Glass pots vary much in size and shape, the larger covered ones weighing as much as 4,500 pounds. Great care must be taken in their structure, as in use they are subject to the most intense heat and at the same time to the action of such powerful fluxes as potash, soda and lead oxides, constituents of the batch of molten material which they contain. Their cost is therefore necessarily great, while their days of usefulness are few, as at the best they wear out in a few months. With near 50 large glass factories in active operation in Indiana it seems strange that no attempt has heretofore been made to utilize the clays of the State in making the pots and tank linings. Two clays are found in western and southern Indiana which are undoubtedly of sufficient purity for the purpose. One is the Montezuma fire clay, which, according to careful analysis, contains but 1.79 per cent. of fluxes, the other, the Lawrence County kaolin, containing 1.97 per cent.* The analyses were made from average samples chosen hurriedly, and if careful selection be made much material of even greater purity will be found in the deposits mentioned.

A plastic refractory clay found in Greene County has been put to a novel use by Mr. P. J. Harrah, of Bloomfield. The clay is mixed with one-half of its bulk of sawdust and then molded into an oval mass a little larger than a hen's egg, and with four grooves running lengthwise. During the process of burning the sawdust is destroyed, leaving a porous mass of fire-clay of great refractoriness. A handle of copper wire is attached to this by an ingenious machine, and a *fire kindler* is complete. This, when dipped into a can of coal oil and allowed to remain over night, absorbs enough oil to burn for 15 or 20 minutes with a flame sufficient to kindle either wood or coal fires. During the two years of 1894–'95 over 300,000 of these kindlers were sold, yielding a handsome profit to the inventor, and showing one of the manifold uses to which a refractory clay can be put.

The following table shows some statistics of the two fire-brick factories of Vermillion County:

---

* For complete analyses see pages 130 and 105.

Statistics of Fire-Clay Factories.

NAME OF FIRM.	Location.	Began Operat'n.	Products.	Number and Kind of Kilns.	Kiln Capacity.	Capital In-vested.	Hands Empl'd.	Average Daily Wages.	Value of Annual Output.	Amount of Fire-clay Shipped.	Value of.
Montezuma Fire-brick Works.	Montezuma, Ind.	1872.	Fire-bricks, boiler tile, cupola blocks, floor brick and ground fire-clay.	Five round down draft.	200,000 fire-brick.	$32,000	35	$1.10	$25,000	2,000 tons.	$3,000
Hillsdale Fire-brick and Tile Co.	Hillsdale, Ind.	1888.	Same as above.	Four round down draft.	150,000 fire-brick.	$20,000	17	$1.25	*$4,000	1,100 tons.	$1,050

* These figures are for 1895, when the plant was in operation only one-third of the time.

THE MANUFACTURE OF POTTERY.

The making of the cruder forms of pottery, earthenware and stoneware, has long been carried on in the coal-bearing counties of Indiana. The early settlers discovered along the sides of the ravines and hills of those counties many outcrops of the under-clays of the coal seams. These, by long exposure, had been rendered soft, plastic, and in every way suitable for the making of such wares as jugs, crocks, etc. At the present time but 11 potteries making stoneware, and in a few instances earthenware, are found in the area covered by this report. Of these, eight are small concerns supplying only a local demand. The other three are larger and ship their output to distant markets. In addition to these, one factory making white granite or ironstone ware on an extensive scale is located at Evansville.

Of the three kinds of ware made in these factories earthenware is the lowest and crudest. Examples of such ware are flower pots, cuspidors and hanging baskets. These are made from any clay plastic enough to work freely, and sandy enough to dry and burn without cracking. A porous, unglazed, unvitrified body is desired, and hence the burning is not extended nor the temperature high.

Stonewares rank next to earthenwares in the scale of pottery products. They are distinguished from the latter by the fact that they are always glazed and usually vitrified, the glazing and burning being accomplished at the same time; whereas in the higher forms of potter's wares two operations are necessary.

Stoneware, to be of good grade, requires much care in the selection of the clay. This must possess certain essential qualities, which may be enumerated as follows:

1. Excessive plasticity, so that it may be easily spun or molded into any desired shape.
2. It must be refactory enough to stand up under the heat required to melt the glaze, and must contain enough free silica to prevent air-cracking while drying, or in cooling after burning.
3. It must possess fluxes sufficient to cause vitrifaction to partially take place at or below the temperature required for glazing.
4. It must be relatively free from such impurities as particles of lime, iron sulphide, etc., which will cause a flaking or blistering of the surface after burning.

Numerous clays possessing these properties exist in the coal area of Indiana. Among the best are those found in the vicinity of Annapolis, Parke County; Brazil, Clay County; Shoals, Martin County; Huntingburg, Dubois County, and Cannelton, Perry County, detailed mention of each of which is given in the previous chapter.

In the smaller factories the clays are usually weathered for some months before using. They are then ground for some time with the old-fashioned horse power machines. This grinding causes the clay to become very tough and waxy; but does little towards removing the impurities.

In the larger factories a machine run by steam and called a "tracer" is used for grinding. By this the clay previously moistened is ground, kneaded and stirred for an hour or longer until the grains have been reduced to as near a uniform size as possible, and the property of plasticity strongly developed.

The clay prepared by either of these two methods is then removed to the turning room, where a piece is cut off of sufficient size and weight to make the vessel desired. This is cut into two pieces several times by a wire and each time reunited by throwing one mass with much force against the other. By this means, and by kneading, the air bubbles are worked out and the particles of the clay brought into closer contact. The clay is then thrown onto a horizontal disc, or wheel, which can be made to revolve rapidly by a foot lathe, or other power. By moistening the revolving mass and pressing it with the fingers, the experienced potter can cause it to take any desired shape.

The amount of ware turned in a day varies much according to the size and kind. So many gallons usually constitutes a day's work. A practiced potter can make as many as 125 to 150 gallons of crocks or jars; while 70 to 90 gallons of jugs will be a good day's labor.

In the larger factories at Cannelton and Evansville, much of the ware is formed by jollying or moulding. By this process a rapidly revolving mold is filled with soft clay. The mold regulates the outside shape of the vessel, and a "shoe" or inner piece, the inside shape. The mold is then taken into a hot closet when the water of the clay evaporates, and the ware shrinks and loosens in its case. The handles are put on after the ware is removed from the mold. By this process a single mold can be used several times a day, and many more pieces of ware can be made by one man than by the old fashioned mode of turning.

The ware after being shaped on the wheel, or by jollying, is set on board shelves in open racks, or in large airy rooms where it slowly dries. After drying, if the glazing is to be that of a slip clay, it is dipped into a solution of such clay, and then, after allowing this to dry, is removed to the kiln. There, at the proper temperature, the slip melts and forms a smooth and handsome surface, usually of a dark brown color.

If the glaze is to be one of common salt, the ware is removed directly from the drying room to the kiln without being dipped into a glaze bath, and when the contents of the kiln are at a white heat the salt is thrown on the fire. Its vapors pass upward and form a brownish yellow glaze on the outside of the ware.

The most of the stoneware made in Indiana is burned in the old-fashioned updraft kilns, the process occupying about 36 hours. Three days must elapse after the fires are drawn before the kiln be opened, else much ware will be spoilt by air-cracking. An ordinary round downdraft kiln of about 20 feet diameter is used by some potters with excellent results.

The potters of Indiana, as far as possible, use the Brazil block or non-caking coal for burning their wares. This coal contains less sulphur than the ordinary bituminous coal, and they claim that for that reason a much better and smoother glaze can be secured with it.

The Crown Pottery Co., of Evansville, was organized in 1891, for the purpose of making ironstone china and decorated tableware. The materials used are none of them obtained in Indiana, and consist of feldspar, flint, ball-clay and kaolin, the latter from Florida and North Carolina. On account of the removal of the tariff on such goods, the market became flooded with similar wares of English make, and the factory was compelled to close down four months in 1894, and three months in 1895. Of the 160 hands employed, 50 are girls who receive $3.00 to $4.00 a week; 60 are boys at $4 00 per week, and the remainder are men at $2.00 per day. The capital stock of the company is $75,000, and the value of the annual output, when run steadily, is $100,000.

The following table gives the statistics of the stoneware factories located in the coal area of the State, as far as they could be obtained:

Statistics of Stoneware Potteries of Southwestern Indiana.

Names of Present Owners.	Location.	Began Operation.	Products.	No. of Kilns.	Kiln Capacity in Gallons.	Annual Output in Gallons.	Value of Annual Output.	Capital Invested.	No. of Hands Employed.
Atchison & Lee.	Annapolis, Parke County.	1841	Stoneware.	1	2,000	40,000	$2,400	$2,500	6
Dr. J. L. Myers.	Bloomingdale, Parke County.	1890	Stoneware.	1	2,000	10,000	$600	$1,000	3
Jas. H. Baker & Son.	Rockville.	1872	Stoneware and Earthenware.	1	2,300	25,000	$1,500	$1,500	3
Torbett & Baker.	Brazil.	1859	Stoneware and Earthenware.	1	2,000	20,000	$1,200	$1,500	3
Beryl Griffith.	Clay City, Clay County.	1846	Stoneware and Earthenware.	1	1,500	40,000	$2,500	$2,000	3
George Baker.	Worthington, Greene County.	1875	Stoneware.	1	1,500	10,000	$600	$1,500	2
Indiana Clay and Specialty Works.	Shoals, Martin County.	1870	Stoneware and Earthenware.	1				$15,000	
V. Walz.	Huntingburg, Dubois County.	1877	Stoneware, Earthenware, Stone Pumps and Drain Tile.	1	2,500	35,000	$2,000	$5,000	4
A. D. Clark.	Cannelton.	1872	Stoneware.	2	2,500	125,000	$5,000	$7,500	10
Cannelton Stoneware Company.	Cannelton	1892	Stoneware and Earthenware.	2	5,000	175,000	$7,500	$5,000	12
Indiana Pottery Company.	Evansville.	1891	Stoneware.	2	8,000	125,000	$5,000	$15,000	
Woods Bros.	Spencer.	1890	Earthenware.	1			$800		3
Total.					29,300	605,000	$29,100	$57,500	49

THE MANUFACTURE OF DRY PRESSED BRICK.

The manufacture of dry pressed brick for the fronts of buildings has become a prominent industry in recent years. Architects and builders are constantly inventing new designs in which these bricks can be used to advantage, and the manufacturers, fully alive to every opportunity for increasing their business, are competing with one another in improving the quality and variety of their output Five large factories have started up in the coal counties since 1890, and all of them are enjoying a prosperous business.

Clays of various kinds are used in the making of dry pressed brick. Surface clays, where free from particles of lime and iron ore, make a handsome red brick; but oftentimes one which is too tender or brittle, the edges being easily broken or rubbed in shipping. Recent sedimentary clays make a tougher brick, but the color can not always be relied upon.

The toughest and most uniform colored pressed brick are undoubtedly those made of shale. Some shales, as those of the "Knobstone" formation at Gosport, and a few of the more refractory deposits of the Carboniferous, can be made into a handsome and durable buff shade of brick, which is rapidly coming into popular favor. The under clays of the coal seams are also utilized in making buff brick, and by mixing them and the shales or surface clays in varying proportions many different shades can be produced at will.

The only preparation necessary for the clays is grinding and screening. The surface and sedimentary clays are usually ground in a pulverizer; the shales and fire clays in a dry pan. The grinding should be prolonged enough to render the particles of clay as near a uniform size as possible. From the screens the clay passes down to a receiver or hopper above the brick press. The latter is a powerful machine, which takes the ground and screened clay, and by the exertion of great pressure forms it into a dense, compact brick. As this is made without the aid of moisture it is but little more than an aggregation of particles of clay, held together by the force of adhesion. Such brick are therefore acted upon and worn away readily by friction, and require careful handling, both before and after burning.

The brick are usually removed from the machine direct to the kiln, though in some places, as at Evansville, an intermediate drying takes place by the progressive or tunnel system. The burning is accomplished in down-draft kilns, either round or rectangular in form; the Eudaly being a favorite kiln for the purpose. The process occupies 16 to 18 days, half of which is devoted to "water smoking." Wood is generally used for fuel in this preliminary process, and coal for the later stages of burning. Where the brick are tunnel dried a shorter time is required for the burning.

After cooling, the contents of the kiln require careful assorting, as several, sometimes a dozen, different shades of one color are present, owing to the variations in burning and the position occupied by the different courses of brick in the kiln.

***

Although a distinct industry the manufacture of roofing tiles from clay will be briefly treated in this connection. But one factory, operated by the Wabash Roofing Tile Co., of Montezuma, Parke Co., is represented in the State. This company began operations in 1889, but suffered losses by fire and business complications so that only in the past two years has the business been conducted on a paying basis.

The tiles are quadrangular, flat and grooved, with overlapping edges, and are $6\frac{1}{2} \times 10\frac{1}{4}$ inches in size. They are made from the soft drab shale found so abundantly in the vicinity of Montezuma. This shale is ground and tempered in a wet pan, and passes from that to a stiff-mud machine which forms it into a large block and cuts this into thin sections of the desired size. These sections, or "slabs," are then pressed on Raymond represses into the requisite shape. From the represses the tile are taken to the racks in the drying rooms where they are subjected to steam heat for 72 hours. They are then placed in saggar blocks and taken to the kilns where they are burned for five days and nights. During the burning they are heated as nearly as possible to the point of vitrifaction, but are not allowed to become fully vitrified, as the thin clay sections are apt to be warped and twisted by extreme heat.

When properly burned the tile are a bright and handsome shade of red, and possess strength and toughness sufficient to bear all necessary transportation and handling. They weigh 600 pounds to the square, and form a roof strong enough to readily support the weight of an average-sized man while walking over it. The capital invested by the company at the present time is but $12,000. Twenty men are employed, and the daily output at full capacity is 20 squares, which bring $6.50 each on board the cars.

The tile find a ready sale in Chicago, Terre Haute and other points, and the business of the company is steadily increasing year by year. No more handsome or durable material than these tile can be used for roofing purposes; and in artistic effects they can not be surpassed, especially on roofs which are designed for their use.

The following table of statistical information was gathered concerning the pressed brick factories found in the area covered by this report:

Statistics of Dry Pressed Brick Factories, etc.

Name of Firm.	Location.	Began Operation.	Number and Kind of Kilns.	Total Kiln Capacity.	Kind of Machinery.	Capital Invested.	Annual Output.	Value of Annual Output.	Number of H'nds Empl'd.	Average Daily Wages.
Cayuga Pressed Brick Co.	Cayuga, Vermillion County, Indiana.	1892	Four Boyd and one Eudaly, squ re, down-draft. One round, down-draft	445,000	Two 9-foot dry pans; two Boyd & White brick machines.	$100,000	5,000,000	$50,000	40	$1.25
Hillsboro Pressed Brick Co.	Hillsboro, Fountain County, Indiana.	1895	Two Eudaly, square, down-draft.	280,000	One 7-foot dry pan; one "Penfield" brick machine.	$30,000		$25,000	20	$1.35
Terre Haute Pressed Brick Co.	Terre Haute, Indiana.	1894	One Eudaly, square, down-draft. One round, down-draft.	185,000	One "Williams" pulverizer; one "Simpson" brick machine.	$30,000	2,000,000	$25,000	20	$2.00
Huntingburg Pressed Brick Co.	Huntingburg, Dubois County, Indiana.	1893	Three Eudaly, square, down-draft.	375,000	One clay pulverizer; one "U. S." brick machine.	$30,000	2,500,000	$20,000	18	$1.50
Evansville Pressed Brick Co.	Evansville, Indiana.	1892	Four square, down-draft.	400,000	Two 8-foot dry pans; one "Simpson" brick machine.	$25,000	2,000,000	$20,000	25	$1.50
Wabash Roofing Tile Co.	Montezuma, Parke County, Indiana.	1889	Three square, down-draft.	50,000 Roofing Tile.	One 9-foot wet pan; one stiff mud machine; four Raymond "Perfection" repress machines.	$12,0 0	3,0 0 Squares of Roofing Tile	$19,500	20	$1.20
Total.						$227,000		$160,000	143	

THE MAKING OF ORDINARY BRICK AND DRAIN TILE.

Ordinary brick and drain tile are the crudest forms of clay wares made in the State, and their manufacture requires but little, if any, technical skill. They form, however, a large proportion of the commercial output of such wares, and the aggregate sum invested in the business of their making is a large one.

The clays used in their structure are either plastic drift or sedimentary clays, both of which are comparatively common in all parts of the State. The only preparation which these clays usually receive is the tempering in crude pug mills. The bricks are made by either hand moulding or by soft-mud brick machines; the tile on a form of the auger machines especially adapted for the purpose. The drying of the bricks is accomplished by the air and sunshine, in open yards, or in racks and pallets protected by sheds. The tile are dried in the latter manner.

The burning of tile usually takes place in round, down-draft kilns, of small dimensions. The bricks are burned either in permanent, clamp up-draft kilns protected by sheds; or, in the smaller yards, in the old-fashioned temporary casing or scoving kilns, each of which is but a nine-inch wall put up around a green kiln and taken down after each burning. The clamp kilns are far superior, and in the long run more economical; as the labor of rebuilding the kiln at each burning is saved, and a much larger percentage of the bricks burned are first-class.

The stiff-mud process of making ordinary brick has not gained much headway in Indiana. Such a process is best suited to a plastic unctuous clay, but the brick are always more or less imperfect, and adapted only for inside work. The soft-mud machine makes a brick of better structure, but each brick has one rough side where the mold is struck off. Brick made by hand are freer from structural faults than by either of the machine processes, but the possible daily output is much smaller.

An attempt was made to gather full statistics relative to the manufacture of ordinary building brick and drain tile in the counties covered by this report. Blanks were sent to each manufacturer, and many of the yards were visited personally. The following table, while not complete, owing to the failure of a small number of the makers to return the blanks, gives the more important facts concerning the industry. The figures are for 1895, and according to statements of the brick and tile makers, represent only about two-thirds of the average annual business. The continuous drouths of recent years have greatly diminished the demand for drain tile, and the general business depression that for ordinary building brick.

Statistics of Ordinary Building Brick and Drain Tile.

Name of Maker.	Location.	Capital Invested.	How Moulded.	How Dried.	Annual Output in 1895.	Value of.	No. Hands Employed.	Average Daily Wages.	No. of Months Worked.
Bracken & Elliott.	Rockville.	$1,500	"Hoosier and Eagle" Machines.	Open yard.	400,000	$2,200	6	$1.25	6
J. G. L. Myers.	Bloomingdale.	$1,500		Sheds and pallets.			6	$1.00	6
W. H. Prather.	Covington.	$1,200	Hand.	Open yard.	200,000	$1,200	8	$1.35	3
J. M. Booe & Son.	Steam Corner.	$2,500	"Ohio" Brick and Tile Machine.	Sheds and pallets.	50,000 and 90,000 tile.	$1,850	4	$1.00	5
Daniel Carpenter.	Mellott.	$4,000	"Hoosier" Machine.	Sheds and pallets.	25,000 and 110,000 tile.	$1,650	5	$1.25	6
Geo. F. Holder.	Attica.	$2,000	Hand.	Open yard.	300,000	$1,650	10	$1.50	6
Jas. A. Furr.	Steam Corner.	$2,000	E. M. Freese Auger Tile Machine	Sheds and pallets.	100,000 tile.	$2,000	6	$1.15	5
Geo. W. Campbell.	Toronto.	$3,000	Terre Haute Tile and Brick Machine.	Sheds and pallets.	40,000 and 72,000 tile.	$1,500	4	$1.25	5
Omara Bros.	Terre Haute.	$6,000	Hand.	Open yard.	1,100,000	$6,000	16	$2.00	6
Wm. Baker.	Terre Haute.	$2,000	Hand.	Open yard.	800,000	$4,400	7	$2.00	6
W. Bergmann.	Terre Haute.	$5,000	Hand.	Open yard.	1,000,000	$5,500	14	$2.00	6

Statistics of Ordinary Building Brick and Drain Tile—Continued.

NAME OF MAKER.	Location.	Capital Invested.	How Moulded.	How Dried.	Annual Output in 1895.	Value of.	No. Hands Employed.	Average Daily Wages.	No. of Months Worked.
Chas. Hoff.	Terre Haute.	$10,000	Hand.	Open yard.	3,500,000	$18,000	40	$2.00	7
J. Bennett & Sons.	Terre Haute.	$3,000	Hand.	Open yard.	1,700,000	$9,350	14	$2.00	6
Emil Teitge.	Terre Haute.	$4,000	Hand.	Open yard.	500,000	$2,500	15	$2.00	6
Henry Offen.	Terre Haute.	$1,500	Hand.	Open yard.	350,000	$1,750	8	$2.00	6
Terre Haute Pressed Brick Company.	Terre Haute.	$10,000	"Henry Martin" Machine.	Sheds and pallets.	3,500,000	$20,000	30	$2.00	7
L. O. Sheets.	Riley.	$1,500	"Hoosier" Machine.	Open yard.	400,000	$2,000	11	$1.25	5
Carter Clay Works.	Coal Bluff.	$2,000	Terre Haute Brick and Tile Machine.	Sheds and pallets.	425,000	$2,250	7	$1.20	7
David McGrew.	Lewis.	$600	Hand.	Open yard.	135,000	$900	6	$1.50	2
C. H. Morgan.	Prairie Creek.	$3,000	Hand, and Tile Machine.	Open yard and sheds and pallets.	250,000 and 150,000 tile.	$3,500	6	$1.25	4
Jas. W. Watts.	Sandford.	$1,000	"Richmond" Tile Machine.	Sheds and pallets.	120,000 tile.	$2,000	6	$1.00	2
Clay City Brick Company.	Clay City.	$5,000	"New Anderson" Machine.	Open yard.	800,000	$3,600	18	$1 30	6

Chas. O. Reutschler.	Centre Point.	$1,000	"Old Reliable" Machine.	Open yard.	350,000	$1,925	4	$1 40	2
F. M. Tapy.	Poland.	$1,100	"Tiffany Centennial" Machine.	Sheds and pallets.	90,000 tile.	$1,200	5	$1 00	7
Woods Bros.	Spencer.	$4,000	"Brewer" and "New Departure" Machines.	Sheds and pallets.	200,000 and 2 kilns of tile.	$2,000	9	$1 15	6
Geo. G. Kaiser.	Patricksburg.	$650	"Old Reliable" Machine.	Open yard.	75,000	$375	1	$1 25	4
Jas. F. Hyatt.	Coal City.	$15,000	One "Potts" Soft Mud and One "Plymouth" Stiff Mud Machine.	Sheds and pallets.	2,500,000	$11,000	30	$1 25	6
Taber & Moore.	Quincy.	$400	Hand.	Sheds and pallets.	6 kilns tile.	$720	4	$0 75	3
Wm. E. Routt.	Cunot.		Hand.	Open yard.	75,000	$500	7		2
J. B. Mullane.	Sullivan.	$2,500	Hand.	Sheds and pallets.	850,000	$4,250	12	$1 25	7
Chrisman Bros.	Sullivan.	$1,500	Hand.	Open yard.	675,000	$3,375	11	$1 50	7
Jas. Nichols.	**Sullivan.**	**$1,500**	**Hand.**	**Open yard.**	**400,000**	**$2,000**	**6**	**$1 50**	**7**
J. P. Walls	Carlisle.	$6,000	"Anderson Chief" Machine.	Sheds and pallets.	600,000 and 45,000 tile.	$3,900	6	$1 10	7
W. C. Bennett.	Farmersburg.	$2,000	Hand.	Open yard.	360,000	$3,000	4	$1 65	5
Lyontown Brick Company.	Cass.	$1,000	"Anderson Chief" Machine.	Sheds and pallets.	380,000	$1,900	9	$1 10	4
Jos. O'Neal & Sons.	Shelburn.	$1,000	Hand.	Open yard.	118,000	$590	4	$1.25	2

Statistics of Ordinary Building Brick and Drain Tile—Continued.

NAME OF MAKER.	Location.	Capital Invested.	How Moulded.	How Dried.	Annual Output in 1895.	Value of.	No. Hands Employed.	Average Daily Wages.	No. of Months Worked.
Vincennes Brick & Tile Co.	Vincennes.	$15,000	"Henry Martin" Machine.	Sheds and pallets.	2,000,000	$10,000	20	$1.50	7
F. G. Lutes & Son.	Montgomery.	$3,000	E. M. Greer's Stiff Mud Machine.	Sheds and pallets.			10	$1.25	6
E. N. Dougherty.	Odon.	$3,000	"Quaker" Machine.	Sheds and pallets.	900,000	$4,900	12	$1.10	4
H. Smiley & Son.	Odon.	$4,000	Kells & Sons "Auger" Machine.	Sheds and pallets.	420,000 and 100,000 tile.	$4,300	8	$1.00	6
Brown Bros.	Washington.	$10,000	"Quaker" Machine.	Sheds and pallets.	1,500,000	$7,500	25	$1.25	7
Riester Bros.	Washington.	$4,000	"Quaker" Machine.	Sheds and pallets.	800,000	$4,000	7	$1.25	7
Philip Kretz.	Washington.	$7,000	"Quaker" Machine.	Sheds and pallets.	1,000,000	$5,000	14	$1.25	6
Andrew M. Keck.	Bramble.	$1,000	Hand.	Open yard.	185,000	$925	8	$1.00	2
M. Moran & Sons.	Loogootee.	$500	Hand.	Open yard.	230,000	$1,150	5	$0.80	3
Wm. Lawhead.	Loogootee.		Hand.	Open yard.	200,000	$1,000	4	$1.00	3
Nicholas Melchior.	Jasper.	$800	Hand.	Open yard.	400,000	$1,900	6	$1.35	4

Michael Hochegsang.	Jasper.	$3,000	"Quaker" Machine.	Open yard.	650,000	$3,000	11	$1.35	6
Bockting Bros.	Huntingburgh.	$2,000	Hand.	Open yard.	400,000	$2,000	6	$1.25	6
Wm. H. Stormout.	Princeton.	$3,500	"Little Wonder" Machine.	Sheds and pallets.	100,000 and 60,000 tile.	$1,900	5	$1.00	7
W. G. Kidd	Princeton.	$5,000	"Eagle" Machine.	Sheds and pallets.	1,500,000	$9,750	25	$1.60	6
Potter & Kimball.	Owensville.	$2,000	Hand.	Sheds and pallets.	300,000	$2,000	7	$1.25	7
Johnson Bros.	Oakland City.	$2,000	"Quaker" Machine.	Sheds and pallets.	400,000	$2,700	11	$1.25	6
Thomas Reed.	Petersburg.	$10,000	Potts' Machine, and Kell's Tile Machine.	Sheds and pallets.	750,000, and 8 kilns of tile.	$4,700	18	$1.25	7
Wm. C. Schnute & Co.	Evansville.	$4,000	Hand.	Open yard.	1,000,000	$4,500	8	$1.50	7
Louise Griese.	Evansville.	$2,500	Hand.	Open yard.	500,000	$2,250	8	$1.50	7
Buente & Ioge.	Evansville.	$3,000	Hand.	Open yard.	700,000	$3,150	6	$1.50	6
Wm Schnute.	Evansville.	$5,000	Hand.	Open yard.	1,200,000	$5,400	12	$1.60	7
First Avenue Brick Co.	Evansville.	$15,000	"Creager" Machine.	Sheds and pallets.	3,000,000, and 7 kilns of tile.	$14,500	30	$1.50	7
Henry Alexander.	Evansville.	$2,000	Hand.	Open yard.	400,000	$1,800	8	$1.50	6
Samuel Wagler.	Evansville.	$2,000	Hand.	Sheds and pallets.	500,000	$2,200	8	$1.50	6

Statistics of Ordinary Building Brick and Drain Tile—Continued.

Name of Maker.	Location.	Capital Invested.	How Moulded.	How Dried.	Annual Output in 1895.	Value of.	No. Hands Employed.	Average Daily Wages.	No. of Months Worked.
Suhrheinrich Bros.	Evansville.	$10,000	"Creager" Machine.	Sheds and pallets.	2,500,000	$11,250	20	$1.40	7
Adam Helfrich.	Evansville.	$15,000	"Henry Martin" Machine.	Sheds and pallets.	2,000,000	$9,000	25	$1.50	7
William Meinert.	Evansville.	$3,000	Hand.	Sheds and pallets.	1,000,000	$4,500	10	$1.50	7
Rudolph Buente.	Evansville.	$2,500	Hand.	Sheds and pallets.	600,000	$2,700	7	$1.50	7
Klamer Bros.	Evansville	$3,000	Hand.	Open yard.	650,000	$2,800	6	$1.50	6
William Hertung.	Evansville.	$3,000	Hand.	Sheds and pallets.	500,000	$2,250	8	$1.50	6
Louis Klostermier.	Boonville.	$8,000	Morena Brick and Tile Machine.	Open yard.	600,000	$3,000	12	$1.00	7
Lowell Bros.	Boonville.	$3,000		Sheds and pallets.	15 kilns of tile.	$3,000	6	$1.10	8
Henry Felwisch.	Boonville.	$12,000	"Grand Automatic" Machine.	Sheds and pallets.	1,000,000	$5,000	10	$1.00	7
Cook Bros.	Newburgh.	$2,500	"Penfield" Brick and Tile Machine.	Sheds and pallets.	150,000, and 8,000 rods tile.	$1,200			5
Henry Weihe.	Newburgh.		Hand.	Open yard.	500,000	$2,500	8	$1.50	5

Jarvis & Thene.	Elberfield.	$4,000	Hand.	Sheds and pallets.	500,000	$2,750	6	$1.25	4
Eigenmann Contract Co.	Rockport.	$4,500	Hand.	Open yard.	1,200,000	$6,000	16	$1.25	7
Philip Feigel.	Rockport.	$1,000	Hand.	Open yard.	350,000	$1,750	4	$1.25	5
Anton Dickman.	Tell City.	$1,500	Hand.	Open yard.	500,000	$2,750	7	$1.25	7
Wm. Hampschafer & Son.	Tell City.	$3,000	Hand.	Open yard.	200,000	$1,000	8	$1.25	3
Total.		$295,250			53,343,000 brick and 1,250,000 tile.	$291,510	792		

THE CARBONIFEROUS SANDSTONES OF WESTERN INDIANA.

An Economic Report on the Sandstones of a Portion of Western Indiana, Accompanied by Two Atlas Sheets Showing the Outcrops and Distribution of the Sandstone.

BY T. C. HOPKINS.

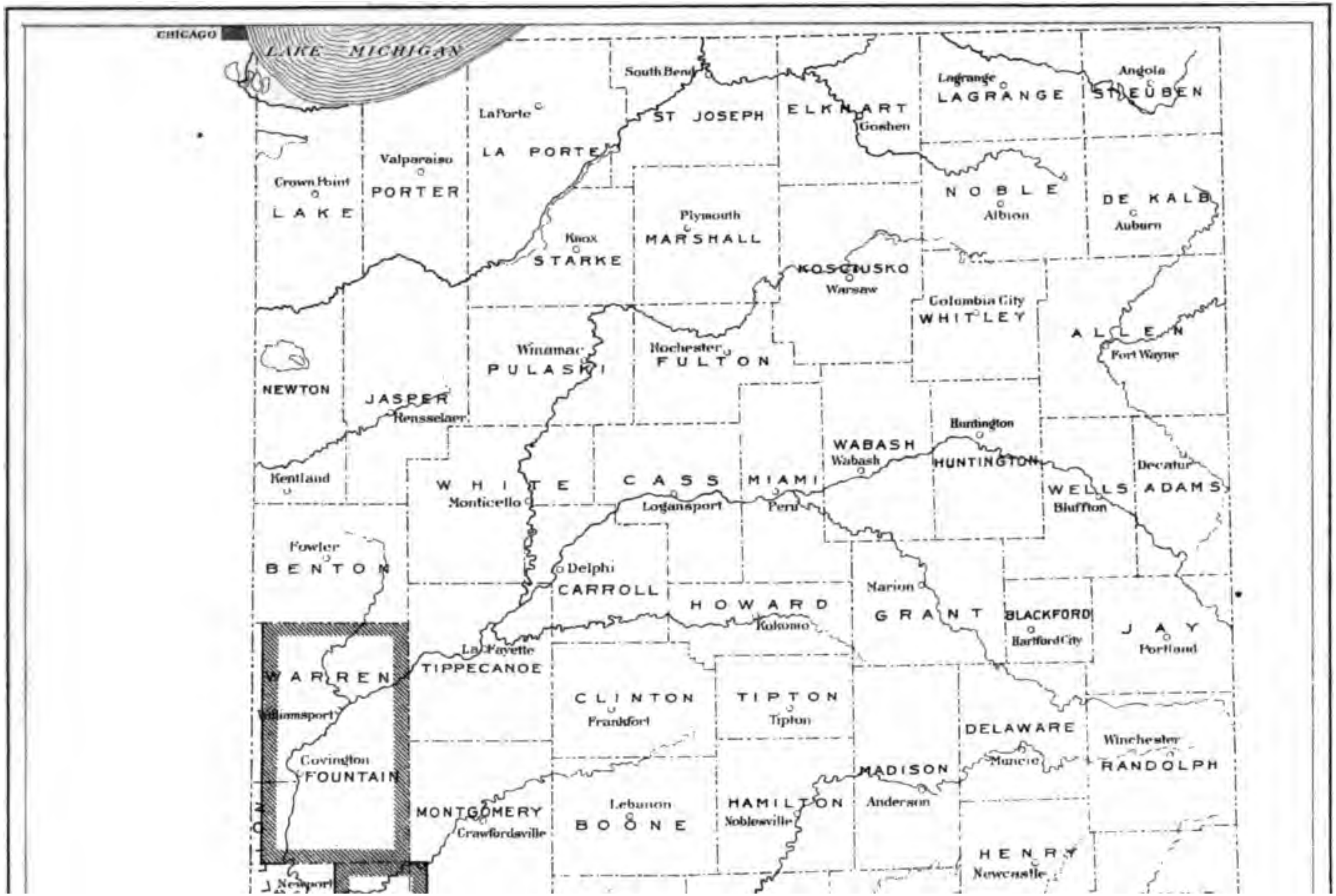
LETTER OF TRANSMITTAL.

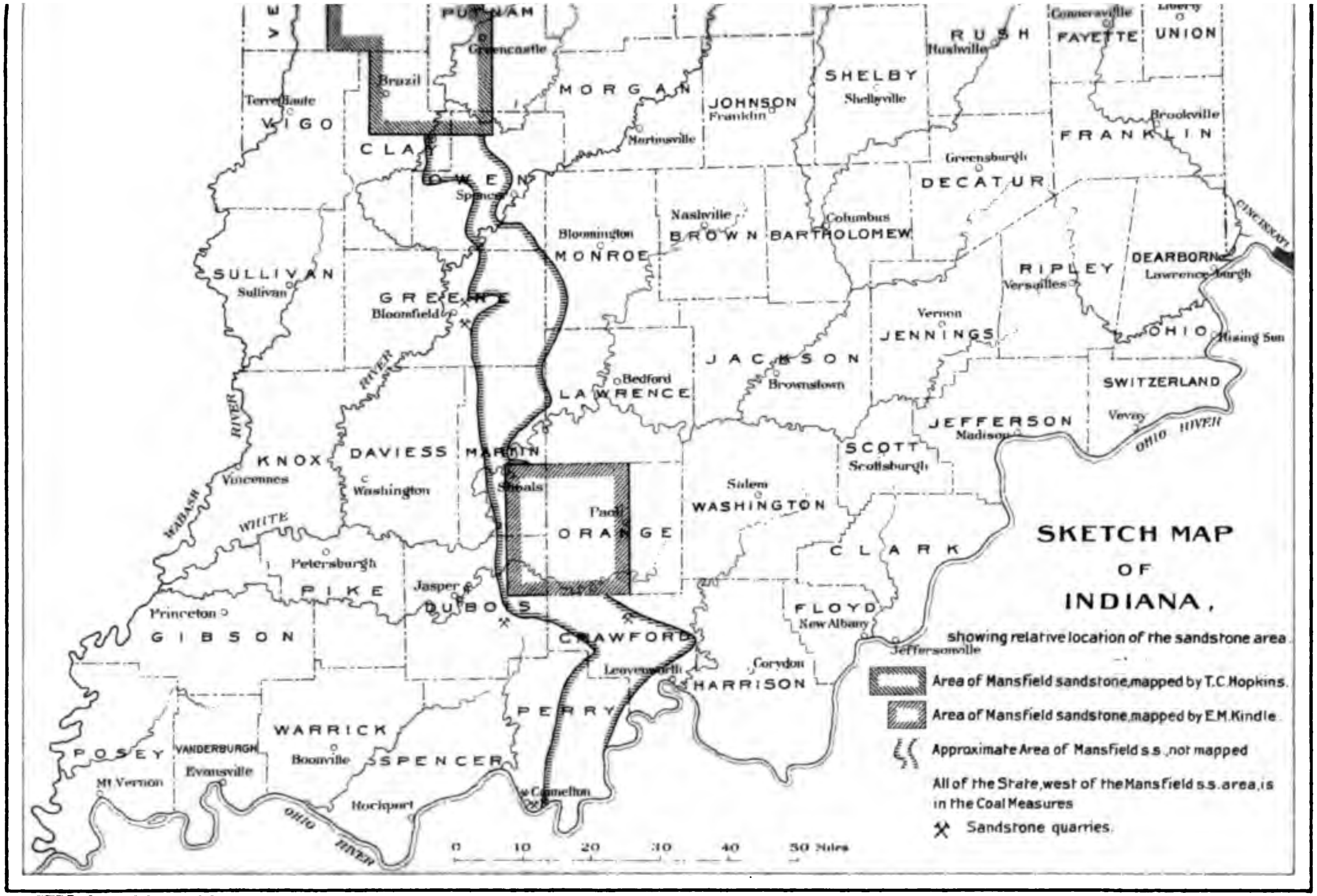
State College, Pa., January 10, 1896.

Dear Sir—Enclosed you will find my report on the Sandstones of Western Indiana, prepared under your directions during the past year.

The map sheets aim at completeness only on the area of the Mansfield sandstone, the outcrops and boundaries of which have been located with some care. Where no reliable township or county maps could be obtained the roads and streams were meandered and checked on the section lines and corners. The railroads are all located from the plats furnished by the companies. The Midland Railway from Brazil to Sand Creek is not given, as no plat of it could be obtained.

The work was conducted as far as possible in such a manner that at any time in the future it could be taken up and carried to completion with a minimum amount of duplication of work. The report on the Mansfield sandstone area embraced on the two accompanying map sheets was made as detailed as practicable. Much of the matter given in Chapter IV. will have only a local value, and to give it local value care was taken to locate as carefully as possible all the sandstone of importance, and to state also where the stone is inferior in quality. Frequently negative information is as valuable as positive on this line. In almost all instances, outside of the few quarries specified, the decision in regard to


CHICAGO
LAKE MICHIGAN
LAKE
Crown Point
PORTER
Valparaiso
LA PORTE
La Porte
ST JOSEPH
South Bend
ELKHART
Goshen
LAGRANGE
Lagrange
STEUBEN
Angola
NOBLE
Albion
DE KALB
Auburn
STARKE
Knox
MARSHALL
Plymouth
KOSCIUSKO
Warsaw
WHITLEY
Columbia City
ALLEN
Fort Wayne
NEWTON
JASPER
Rensselaer
PULASKI
Winamac
FULTON
Rochester
WABASH
Wabash
HUNTINGTON
Huntington
WELLS
Bluffton
ADAMS
Decatur
Kentland
WHITE
Monticello
CASS
Logansport
MIAMI
Peru
BENTON
Fowler
CARROLL
Delphi
HOWARD
Kokomo
GRANT
Marion
BLACKFORD
Hartford City
JAY
Portland
WARREN
Williamsport
TIPPECANOE
La Fayette
CLINTON
Frankfort
TIPTON
Tipton
DELAWARE
Muncie
RANDOLPH
Winchester
FOUNTAIN
Covington
MONTGOMERY
Crawfordsville
BOONE
Lebanon
HAMILTON
Noblesville
MADISON
Anderson
HENRY
Newcastle
Newport



Wm B. Burford Lith. Indianapolis Ind.

the quality of the stone is based on field observation, the texture, structure, and the effect of the weathering influences. Descriptions of localities outside of the area mapped are more or less preliminary and can be completed when the areas are surveyed in detail.

No one realizes more fully than the writer the incompleteness of this report and the impossibility, with the limited resources available for that work, to make more than a beginning at what should be done in this line. Any one at all familiar with the boundless wealth of Indiana in its building materials must realize the importance and value of a thorough investigation of them and their publication in an accessible form. The economy of such work must impress itself on the minds of all business men with the knowledge of the facts.

A thorough investigation of these resources could be made at a cost to the State of less than 10 per cent. of the money it loses each year by (1) the importation of stone from other States, stone often no better and frequently not as good as that found in the State; (2) the loss of markets outside of the State due to lack of proper advertisement of the stone. Building stone is shipped east and west, north and south across our State, right by and over undeveloped beds of good stone; (3) the local usage of inferior stone in the presence of good stone through ignorance of its occurrence and properties. A little money judiciously spent in this line would be returned a hundred fold in the money saved and brought into the State.

Not only should the facts regarding the occurrence, distribution, and the description of the stones be made known, but there should be such physical and chemical tests as will convince the intelligent architect and builder of their value, or what is often of as much importance, their unfitness.

Notes were made on many other localities, particularly in Southern Indiana, which do not appear in this report because sufficient time was not available for putting them in proper shape.

I am indebted to the citizens throughout the area for their uniform kindness and hospitality, and am under special obligations to Mr. Geo. Galloway, of Fountain, and Mr. Jos. Shryer, of Bloomfield.

Whatever merit the report may possess is due in no small degree to your hearty coöperation.

T. C. Hopkins.

To Prof. W. S. Blatchley, State Geologist.

THE CARBONIFEROUS SANDSTONES OF WESTERN INDIANA.

CHAPTER I.

THE GENERAL CHARACTER AND PROPERTIES OF SANDSTONES.

Definition.—The term sandstone includes the granular sedimentary rocks. The grains commonly, but not essentially, are quartz and the cementing substance, which varies widely in quantity, consists of iron oxide, clay, carbonate of lime, or silica. The two essential characters of a sandstone are (1) the grains, (2) the cement. As the grains increase in size the stone grades into a conglomerate; as they diminish in size it passes into shale or clay; as the grains lose their identity in the rock mass it passes into quartzite. If the cementing substance is wholly lacking there is simply a bed of sand, the condition in which probably all the sandstones were at one stage. By the increase of lime cement the rock passes into limestone; by the increase of the clay cement it grades into shale or clay; by the increase of iron, into iron ore; by the increase of quartz, into quartzite.

The composition and character of the grains.—In nearly all the common sandstone the bulk of the grains and sometimes all of them are fragments of quartz.* Other substances frequently occur in small but varying quantities, the most common of which are amorphous silica, feldspar, muscovite, biotite, magnetite, limonite, hematite, pyrite, and glauconite, less commonly apatite, calcite, augite, hornblende, tourmaline, staurolite, zircon, and rutile. Other rarer accessories are galena, cerussite, malachite, barite, garnet, celestite.†

The grains generally represent the least soluble parts of rocks. The soluble portions of the rocks are leached out by infiltrating waters during

*Calcareous sandstones or sandrocks are not uncommon on the seacoast where limestone or many shells occur, these being ground into fragments and cemented by the deposition of lime carbonate. These are rarely met with among the older sedimentary rocks, as they become modified by percolating waters.

†J. Roth, Allgemeine u. Chemische Geologie, Band II, pp. 608-609.

the processes of weathering, while the less soluble portions are transferred by the waves, streams, and currents and deposited as beds of sand and gravel, which harden into sandstone and conglomerates. As quartz is the least soluble of the common rock-making minerals and at the same time one of the most abundant, it thus comes to make up the bulk of the sandstones. However, in the process of degradation not infrequently fragments of fresh material are ground up and deposited in the beds of sand so that sandstones are liable to contain fragments of any or all rock-making minerals.

The grains are usually angular, less commonly rounded, the coarser grained sandstone often consisting of a mixture of the two. Only where the grains suffer friction by wind as in desert sand do they appear to be completely rounded.* Sand grains of very small dimensions, as small as one-tenth of a millimeter, which are transported by flowing water, always remain angular (Daubrée).

Cement.—The common cements of sandstone are clay, iron oxides, calcite, and silica. These may be carried in as sediment in the waters that deposit the sand, or they may be deposited by infiltrating waters subsequently to the deposition of the sand. The material may be deposited with the sand and subsequently changed by the action of infiltrating waters or the materials may be carried in by the waters from some extraneous source. On the character and quantity of the cementing material depends the rigidity or strength, the durability, the workability, and most frequently the color of the stone. Thus from an economic standpoint the cement is by far the more important constituent of the rock, although it frequently forms but a small per cent. of it.

The argillaceous or clayey cement may generally be detected if present in considerable quantity, by giving an earthy odor when breathed upon. It may or may not discolor the stone, the color depending on the purity of the clay; it is more commonly a gray or yellow color, sometimes blue where not much weathered. From the standpoint of durability it is the least desirable of any of the cements, owing to the nature of the clay to absorb water, and thus render the stone liable to injury from frost. The presence of the clay in small quantities intimately diffused through the rock is not necessarily a fatal injury to the stone, as many well-known building stones have a clay cement. It is where the clay is segregated in layers or patches that it is the most injurious.

The ferruginous, or iron oxide cement always colors the stone; the hydrous oxide or limonite forms give various shades of buff, yellow, and yellow-brown, the shade depending on the hydration of the iron and the quantity of it present. The anhydrous or hematite form of the iron gives various shades of red and red-brown depending on the quantity

*Zirkel, Lehrbuch der Petrographie, Vol. III, p. 715.

and character.* Most commonly there is a mixture of shades or colors in the form of spots, stripes, clouds, or veins. The most serious objection to the iron oxide cement is the lack of uniformity in color in the stone. Where the color is uniform, and at the same time pleasing, it makes one of the most valuable building stones, such as the brownstones of Connecticut, Pennsylvania, Lake Superior, and Indiana. Sometimes the iron occurs as finely diffused iron sulphide or ferrous carbonate, and more rarely as the silicate, when the stone has a faint bluish or greenish tint.

The calcite, or lime carbonate cement rarely produces deep or bright colors, and is generally yellow-gray or greenish-gray; it can generally be detected by giving an effervescence with an acid, but it is commonly associated with the carbonates of magnesia and iron, and when the latter carbonates form a considerable per cent. there may be no effervescence with cold acid, but will be when the acid is heated. It makes a durable and desirable stone, providing the texture and structure are all right, but it quite frequently happens that the texture is so close and compact as to make it, exceedingly difficult to work; in some localities where it occurs intercalated with the ferruginous sandstone, it is termed "flint" by the quarrymen, because of its extreme hardness as compared with the more friable ferruginous stone. Very few of the widely known building stones occur in this class.

The siliceous cement is the most durable of any, but if present in considerable quantities it often makes the stone too hard to work with either ease or profit, and changes the sandstone to quartzite, one of the hardest and most durable of rocks. The well-known Sioux Falls stone belongs in this class.

There is commonly a mixture of two or more of these cements as the silica and clay, silica and lime, clay and iron. Not infrequently the pyrite acts as a cement, though not a desirable one.

Bedding surface.—The bedding surfaces are frequently covered with mica scales, clay, marl, or red ironstone. These are desirable, if not present in excess, as they cause an easy parting along the bedding surface, thus facilitating the work in quarrying.

The bedding surfaces are frequently marked by sun cracks, rain drops, ripple marks or wave marks, animal tracks, etc. All of these except the ripple marks denote an exposure of the soft material before it was indurated; probably the bottom of some lake, bay or lagoon has been elevated above the high tide and in drying would form cracks to be filled by later formations and would receive and retain the imprint of rain drops or tracks of animals, etc.

---

* In the Tertiary sandstones of the Eastern States, the iron cement is largely turgite. In the Triassic and Carboniferous sandstones it is largely limonite. In the Potsdam sandstone of Lake Superior it is mostly hematite.—A. Julien. Proc. A. A. A. S., Vol. 28, 1879, p. 408.

Varieties of sandstone depending on color.—Sandstones are white, gray, drab, buff, yellow, brown, red, blue, green, and black, with many intermediate and intermingled shades of these colors. The white sandstones are generally nearly pure silica and practically free from metallic oxides. The gray contains a slight admixture of clay, iron or organic material. The buff, yellow, and brown colors are due to the presence of hydrous oxide of iron; the red to the presence of hematite; the blue color may be due to finely diffused iron pyrites, or the presence of iron carbonate, or a small quantity of bituminous or carbonaceous matter. The faint pale green tint found in some sandstones is probably due to some form of iron protoxide, possibly the silicate; the bright green is due to malachite. The black color is due to bitumen or carbonaceous material of some kind. The depth of color in a rock depends not so much on the amount of coloring material as on the chemical and physical character of it.

Varieties of sandstone based on texture and structure.—Sandstones may be fine-grained, medium fine, coarse, or very coarse, all of which terms are relative and more or less arbitrary in their usage. Orth* has proposed the following distinction to these general terms:

	Millimeters.
Fine sand, diameter of the grains	0.05 to 0.25.
Medium fine, diameter of the grains	0.25 to 0.50.
Coarse sand, diameter of the grains	0.50 to 1.10.
Very coarse, diameter of the grains	1.00 to 3.00.
Gravel, diameter of the grains	3 mm. or more.

The texture may be open and porous, close and compact, friable or earthy. The fine angular-grained highly siliceous varieties with little cement furnish the whetstones. The coarse angular-grained, friable, siliceous varieties form the grit and grindstones.

In structure the stone may be massive, heavy-bedded, thin-bedded or shaly, all relative and self-explanatory terms.

Varieties of sandstones based on composition.—As nearly all sandstones are quartzose in grain, the distinctions in varieties are based on differences in the cementing material as follows:

Siliceous or quartzose sandstone is one in which the quartz grains are bound together by a siliceous cement. This may be quartz deposited on the grains and oriented with them so as scarcely to be distinguishable from the original grain, or it may be in the form of an aggregate oriented independently. In rare cases the silica may be deposited in the form of opal. In most cases the cement is present in small quantities. With the increase in quantity of the siliceous cement the stone becomes harder, passing finally into quartzite, in which the separate grains can no longer

*Zirkel's Lehrbuch d. Petrographie, Band III, p. 736.

be distinguished by the naked eye. The quartzose sandstones are the most durable, but are also the most difficult to work.

Calcareous sandstone has the cement of lime carbonate which may be in varying proportions, sometimes as high as 30 per cent. or more.* The lime carbonate is commonly mixed with more or less iron and magnesia carbonate. In some instances dolomite or the double carbonate of lime and magnesia forms the cement. In rare cases gypsum (lime sulphate), barite (barium sulphate), or celestite (strontium sulphate) forms the cement. The calcareous sandstones are mostly a yellow-gray or greenish-gray color, rarely white or yellow, and they are widely distributed, but more common in the younger formations than in the older ones.

Argillaceous or clayey sandstone is one in which the sand grains are held together by a clay cement. It is the most common of all sandstones, and occurs in formations of all ages. They are usually fine-grained, as a current strong enough to move coarse sand would carry all the clay away, and in the gentle current or still water where the clay would settle there would be deposited all the fine sand that remains in suspension. In their deposition they form an intermediate stage between the coarser sandstones and the clays or shales, and naturally grade from the coarser sandstones into the sandy clays and shales with no sharp line of distinction between them. Mica flakes and feldspar grains are common accessories. The clayey sandstones are white, gray, yellow, green or pale red in color.

Kaolinitic sandstone is an argillaceous one in which the cement consists of kaolin, usually white or gray in color. It usually contains reddish-white fragments of orthoclase in either a fresh or decayed condition.

The *marly sandstone* is intermediate between the calcareous and the argillaceous varieties, and has a cement of clayey limestone or marl. It grades into sandy marl.

The *ferruginous sandstone* has a cement of iron oxide, either the hydrous oxide (limonite, göthite, turgite) or the anhydrous oxide (hematite), or it may be in the form of ferrous carbonate. The iron oxide commonly forms a coating around each of the quartz grains, thus binding them together. In the cement between the larger quartz grains are frequently fine particles of sand, mica flakes and grains of the iron oxide. The ferruginous sandstones, as a rule, are very poor in organic remains. They occur in rocks of all ages, especially abundant in the Devonian, Permian, and the Triassic, such as the Old Red sandstone of England and the famous brownstones of the eastern States.

Glauconitic sandstone is so called from the glauconite it contains. While of some scientific interest it has little economic value.

Bituminous sandstones have a perceptible amount of carbonaceous material diffused through the mass, giving them a dark gray or even black

*Zirkel, Lehrbuch der Petrographie, Band III, p. 724.

color. They are not so common as some of the other varieties, and rarely have any economic value. The bituminous material sometimes takes the form of asphalt.

Varieties of sandstone based on locality.—These may have acquired a geologic significance, and designate a definite horizon, such as the Potsdam sandstone, Calciferous sandstone, Medina, Clinton, Oriskany and Catskill sandstones, etc. Or they may be simply commercial terms without reference to geologic position, and known in the market by the name of the place at or near which they are quarried. The varieties on this basis are almost as numerous as the quarries. Among the best known brownstones are the Portland (Conn.), Hummelstown, Lake Superior and the Sioux Falls, the latter being a quartzite. The Berea and the Cleveland stones of Ohio are widely known. Among the best known sandstones in Indiana are the Cannelton, St. Anthony, Williamsport, Riverside, and Mansfield sandstones.

Uses of sandstone.—Sandstone is subject to all the uses of other building stones. It is probably better adapted to use in heavy masonry, as bridge abutments, foundations, retaining walls, etc., than almost any other class of stones, owing to the greater ease with which it can be quarried. It compares favorably with other stones in superstructures, the far-famed brownstones of the eastern States being one of the most fashionable building stones in the country, while there are others less widely known but equally as good, and often much better from a standpoint of durability. Many sandstones which are good, durable, and desirable wall stones are not suited for trimmings, such as lintels, sills, caps, etc., on account of weak transverse strength. Some varieties, however, especially those with siliceous cement, are very strong in this direction and well suited for such purposes. On account of the varieties in color which can be obtained they are often desirable for architectural effect in trimming buildings of brick or other varieties of stone.

The proportion of the sandstone quarried that is used for building purposes is greater than that of either limestone or granite. The census report gives for 1889 the following percentages of all the stone quarried that was used for building purposes: Sandstone 65 per cent., granite 43 per cent., and limestone 23 per cent.

The harder varieties of sandstone are desirable for steps and pavements as they are not so slippery as limestones and granites. Some of the softer sandstones that are otherwise very durable do not stand abrasion sufficiently well to be used for this purpose. Some of the largest flagstone quarries of the country are in sandstone. It is also used for curbing, sewer caps, etc., but care should be taken to select only the harder forms for such uses.

Sandstone has been used for paving blocks, but only the harder or quartzitic forms are suitable for this purpose. It is suitable for railway ballast or for macadam for wagon roads. In the latter case there should be a top dressing of gravel or harder rock. Nearly all the grindstones, whetstones and shoe rubbers are of sandstone, where the grains are sharply angular and the cement in small quantities. Sandstone that is light colored, highly siliceous and free from iron is used for glass making. Sandstones that stand the fire well are sought for use in furnace hearths.

The following list, showing the various uses of sandstone is taken from the Stone Industry in 1894, by W. C. Day: *

USES TO WHICH SANDSTONE IS PUT.

FOUNDATIONS, SUPERSTRUCTURES, AND TRIMMINGS.

Solid fronts,	Buttresses,	Capping,	Ashlar,
Foundations,	Window sills,	Belting or belt courses,	Forts,
Cellar walls,	Lintels,		Dimensions,
Underpinning,	Kiln stone,	Rubble,	Sills,
Steps.			

STREET WORK.

Paving blocks,	Basin heads or catch-basin covers,	Road-making: Macadam, Telford, Concrete, Sledged stone, Crushed stone.
Curbing,	Stepping stones.	
Flagging,		

ABRASIVE PURPOSES.

Grindstones,	Whetstones,	Shoe rubbers,	Oilstones.

BRIDGE, DAM AND RAILROAD WORK.

Bridges.	Breakwater.	Rails.	Bankstone.
Culverts.	Jetties.	Ballast.	Parapets.
Aqueducts.	Piers.	Approaches.	Docks.
Dams.	Buttresses.	Towers.	Bridge covering.
Wharf stone.	Capstone.		

MISCELLANEOUS.

Grout.	Lining for blast furnaces.	Millstones.
Hitching posts.	Rolling-mill furnaces.	Fluxing.
Fence wall.	Lining for steel converters.	Ganister.
Sand for glass.	Fire brick, silica brick.	Glass furnaces.
Sand for plaster and cement.	Core sand for foundries.	Random stock.
Furnace hearths.	Adamantine plaster.	
	Cemetery work.	

Production of sandstone in the United States.—The value of the sandstone production as compared with that of other stones for the last two years, and the value of the sandstone quarried in the different States for the last four years as compiled by the U. S. Geol. Survey, are shown in the tables in the final chapter.

* The Stone Industry in 1894, by W. C. Day. In the Sixteenth Annual Report of the Directo of the United States Geological Survey, Part IV, Washington, 1895.

While there is a marked reduction in the production of sandstone from 1890 to 1894 it may be noticed that Indiana, which ranked 22d in the value of its production in 1890, ranked 15th in 1894.

It might be further noticed that the report shows the production for 1891 in Indiana valued at $90,000, while the statistics collected by the State Geologist of Indiana for the same year show a value of $169,411. So the value for 1894 should be $77,800 instead of $22,120. Even these values given by the State Survey are low, as it is impossible to get the figures from the small quarries.

Distribution of sandstones.—Sandstones are distributed geologically throughout the sedimentary series from the oldest to the youngest strata. The Potsdam sandstone of early Paleozoic, the Old Red sandstone of Devonian and Permian times, the Millstone grit of Carboniferous and the Portland and other brownstones of Triassic times are all heavy and widespread formations.

Geographically they are almost as widespread as the sedimentary rocks. Extensive beds of valuable sandstone occur along the Atlantic seaboard States in the folded regions of the Appalachians, bordering the coal areas of the Mississippi Valley, bordering the crystalline series in the lake region, and in the Cordilleras of the west. As shown by the statistical tables the States that lead in the production of sandstone are Ohio, Pennsylvania, Connecticut, New York, New Jersey, Massachusetts, and Missouri. In 1890 Colorado and Michigan were important producers.

CHAPTER II.

GEOLOGIC HISTORY OF THE SANDSTONES OF WESTERN INDIANA.

All the sandstones mentioned in this report belong to the Carboniferous age, some in the Lower Carboniferous, some in the Coal Measures. Detailed work was done on only one bed, that at the base of the Coal Measures and termed the Mansfield sandstone. Others are mentioned and certain economic features described as they appear at certain localities without attempt to accurately designate their stratigraphic position or their areal extent, which would require more time than was available in this work.* The general relations of the different sandstone deposits are as follows:

* The reasons for the detailed work on the Mansfield stone rather than on the others are (1) its greater economic importance, (2) the others are associated with other economic products which will require investigation in the future, when the details of both can be worked out together.

I. Coal Measures.

1. A series of coal beds separated by sandstones, shales, fire-clays, and, in places, limestone; more or less loosely classified in certain areas, but no reliable general correlations over the whole area; good sandstone in several localities.

2. The Mansfield sandstone and conglomerate, a bed of coarse-grained, massive sandstone at the base of the Coal Measures, contains some conglomerate and is accompanied by some coal, black shale, and fire-clay. It is referred to in former State reports as the Conglomerate and as Millstone grit.*

II. Lower Carboniferous or Mississippian.

1. The Riverside sandstone.	Chester.
2. Several beds of associated limestones, shales and some sandstone, probably corresponding to the following groups.	St. Louis. Keokuk. Knobstone.

There are many local variations in the character of the strata, and it will require more detailed paleontologic and stratigraphic work than has yet been done to give any scientific value to a correlation of them with strata at localities outside of the State.

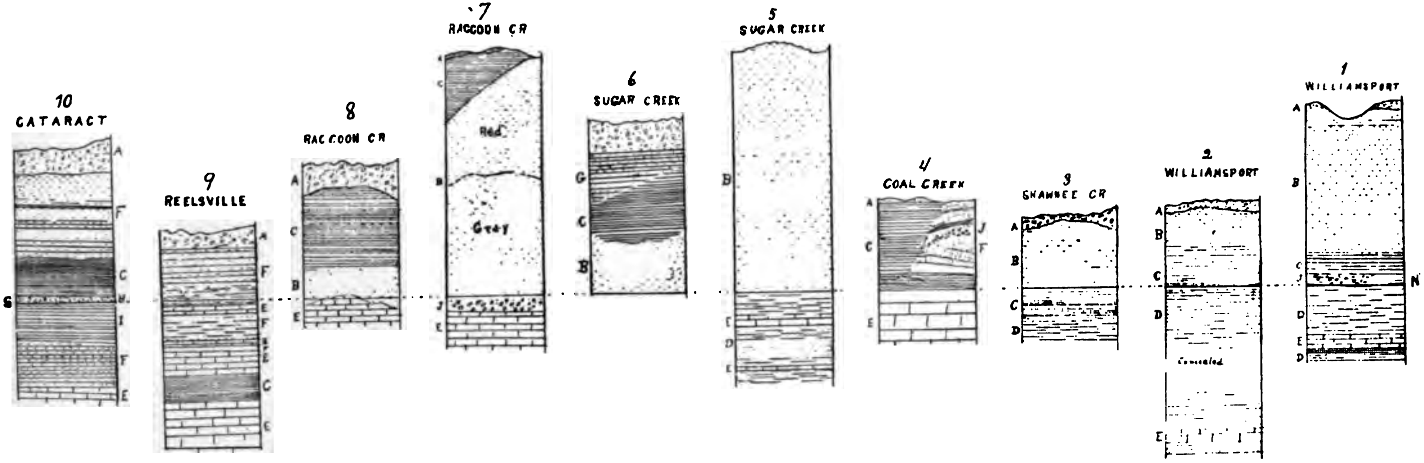
There are heavy beds of sandstone in the Coal Measures at Cannelton, at the Portland quarry in Vermillion county, on Big Vermillion river, on Little Vermillion river, at Covington, at the Glen south of Covington, at Silverwood, on Sugar creek and elsewhere, but not enough is known at present to say whether they all belong to the same or different periods of deposition

In the north part of the area mapped the Coal Measures are underlain by a fine-grained, impure sandstone (the Riverside sandstone of this report), associated with thin layers of limestone in some places. In the southern part of the area mapped (the Brazil sheet) they are underlain by a compact blue limestone, in some places cherty, in some places not. Still further south, about French Lick, they are underlain by alternating layers of compact limestone and coarse, yellow sandstone. The valuable bed or beds of oolitic limestone lie some distance east of the Coal Measures along a certain part of the area, but none of these formations have been accurately delineated either areally or paleontologically.

Some of the local variations of the strata are shown on plate IX., which consists of a series of sections from different parts of the area. These sections are arranged in a general way from north to south, yet it frequently happens that a section less than a mile away may show a greater change than one ten or even fifty miles away.

Unconformity.—The line of parting between the Lower Carboniferous strata and those of the Coal Measures is in a great many places marked by an unconformity shown by the erosion interval and the occurrence of the basal chert conglomerate. Plate X. illustrates some well-marked examples of this unconformity. It would be all the more

* The reasons for the use of the term Mansfield are given in a succeeding chapter.



A SERIES OF SECTIONS ARRANGED IN A GENERAL NORTH-SOUTH DIRECTION, ILLUSTRATING THE LOCAL VARIATIONS IN STRATIGRAPHY.

N-S—Line of parting between the Lower Carboniferous and the Coal Measures.

A—Glacial drift.
B—Mansfield sandstone.
C—Black shale.
D—Riverside sandstone and shale.
E—Limestone.
F—Shaly sandstone.
G—Flagstone.
H—Fire-clay.
I—Green shale.
J—Conglomerate.

marked in some places by a longer section. Thus a section across the Wabash River valley above Attica would show in one place 90 feet or more of Coal Measure sandstones in the bottom of the valley, and the Lower Carboniferous rocks on the hills on either side. Likewise on Sugar creek, in one place the massive Mansfield sandstone outcrops 100 feet thick, extending below the level of the creek, while less than a mile away the underlying Lower Carboniferous limestone is 80 or 90 feet above the creek. This is not due to the dip of the strata, which in most places are practically horizontal, but to erosion of the underlying rocks before the deposition of the Coal Measures.

Conditions of deposition.—During the deposition of the Lower Carboniferous limestone there was a ong period of quiet seas, and probably little elevation or depression of the earth's crust. At the close of this limestone-making period there was an elevation, probably very gradual, and a long period of oxidation, with more or less erosion, began. Before this had quite reached base level, a higher and more rapid elevation took place, when the streams were all quickened in their erosive power, and the coarse oxidized residual deposits of the preceding period were swept down by the strong currents to the sea shore, to the bays, estuaries and river channels, where they were deposited to form or to assist in forming, the massive, coarse-grained sandstone and conglomerate at the base of the Coal Measures.

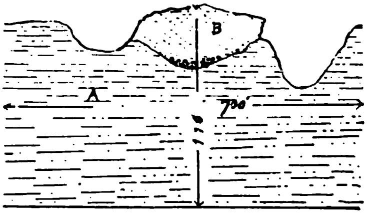
Source of material.—The source of all this coarse material is not easy to explain. One naturally looks to what was then the land area to the east, but there are no coarse sandstones and no granitic rocks in that area to furnish the material. There are apparently two sources of coarse, siliceous sediment from the older rocks to the east: (1) the chert in the limestone, and (2) the geodes. That both these are a source of supply is clearly shown in the rocks themselves, in many places the chert pebbles and fragments being found in abundance, not only identical in color and general appearance, but carrying the same fossils as that in the underlying limestone. While the identity of the chert is clear in the coarse basal conglomerate, it is not so evident in the case of the finer grained sandstones, where most of the grains are fragments of crystalline quartz, while the chert is cryptocrystalline, and it is highly improbable that the grains became crystalline after deposition. Furthermore, as mentioned elsewhere the numerous light-colored granular quartz spots in the sandstone are supposed to be chert. Nor can the numerous patches of hard quartz conglomerate have their origin in the chert. Hence, while this is one source, it is not the sole source. The quartz in the geodes is crystalline, and that this is one source of supply for the sand and pebbles can be clearly proven by the presence of geodes and fragments of geodes in the conglomerates. A single hand specimen sometimes contains as high as a half-dozen fragments that still show their geodic origin. That this is not a sole source of supply is evident for two reasons: (1) some of the quartz in the sandstone contains microlites of apatite, rutile, zircon, and fluid inclusions that do not occur in geodic quartz; (2) the product is greater than the source. While it is true that geodic quartz is abundant in some of the beds, and would furnish a vast amount of sand when ground up by the waves and currents, it is not sufficient to furnish all the material for the Mansfield sandstone.

Thus besides the two sources of the material given there must be at least another and that must be from a region of igneous or metamorphic rocks, or from a rock derived from such a source. Such a source is not to be found east of the sandstone area, but must be sought in the north, northwest, or southwest, and in any case the material must be transported a long distance. Three possible explanations that apparently accord with these conditions might be offered to account for the source of such material: (1) It may come from the crystalline areas of the north, transported by the currents of one or more Paleozoic rivers aided perhaps by floating ice. (2) It might come from the older Paleozoic sandstones (the Potsdam and St. Peter's) of Northern Illinois and Southern Wisconsin brought down by shore currents and floating ice. (3) It might have been carried by floating ice across the shallow interior sea from the crystalline island in the Iron Mountain region in Missouri.*

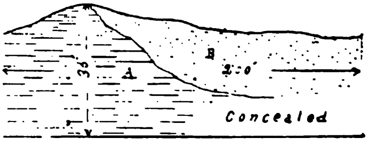
The most serious objection to any of the explanations, but that of a glacial period, is the presence of so many quartz pebbles of large size which would require currents of almost incredible velocity to transport them in one geologic period from Wisconsin, Michigan, or Canada to Southern Indiana and Kentucky. However, these large pebbles may all or most of them come, as some of them evidently do, from the chert and geodic quartz of the older limestones close at hand.

It may sound unreasonable to many geologists that any appreciable amount of sand or pebbles may come from the geodes, and some to whom I have mentioned the subject think that the amount from such a source would be too small to be worthy of consideration. But I am convinced that a study of the field relations as they exist in Indiana would convince any one of the importance of this source of supply. While sufficient evidence is not at hand to prove that all or even the major portion of the coarse materials *did* come from the geodes, there is conclusive evidence that an appreciable quantity of the quartz pebbles *did* come from

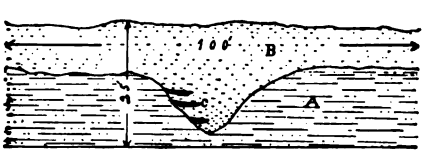
*A fourth possible theory might be suggested, but in the light of present knowledge seems highly problematical, that is a transportation by land from the northern regions by glacial action similar to our recent glacial period. Eastern geologists have shown with considerable clearness the presence of a Carboniferous glacial period in India and in Southern Africa, but there is as yet no such direct or satisfactory evidence that there was such in America, and considering the extent to which the Carboniferous system has been studied in this country, it would seem highly probable that such evidence would have been discovered if it existed.



1. Black Rock.

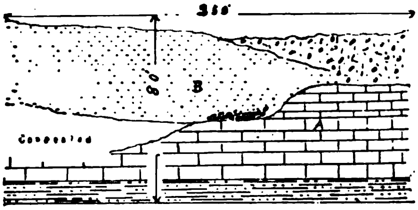


2. Little Pine Creek.

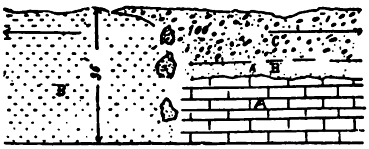


3. Turkey Run.

4. Sugar Creek.



5. Ramp Creek.



6. Byrd Branch.

SECTIONS ILLUSTRATING THE UNCONFORMITY BY EROSION BETWEEN THE LOWER CARBONIFEROUS AND THE COAL MEASURES IN WESTERN INDIANA.

such a source, and it is not impossible or improbable that a considerable portion was so derived.

The sandstones that occur in the productive Coal Measures are in general finer grained than the Mansfield stone, and so far as observed contain no coarse conglomerate. They are less purely siliceous than the Mansfield stone, and possibly a higher per cent. of their materials has been derived directly from the Lower Carboniferous rocks and older strata to the east, which has been carried by the Carboniferous rivers and deposited in the lakes, bays, estuaries, and shallow Carboniferous seas. As there were many more or less shallow basins separated in part by land areas we would naturally expect many local variations in the character of the strata, or rather since we find these local variations along with ripple marks, false bedding, carbonaceous material, etc., we naturally conclude that such was the condition at that time.*

CHAPTER III.

THE MANSFIELD SANDSTONE.†

The Mansfield sandstone, a coarse-grained gray, yellow, red, brown, or variegated massive sandstone is probably the most important sandstone in the State of Indiana, from both an economic and scientific standpoint. There is considerable good building sandstone in the overlying Coal Measures, and to a less degree in the underlying Lower Carboniferous series, but no single formation contains as great a variety or as large a quantity of good sandstone as the one designated in this report, the Mansfield sandstone.

The name.—The formation is named from Mansfield, Parke county, Indiana, a little village on the bank of Big Raccoon creek, twelve miles north of Brazil, with which it is connected by railroad. The name is probably not the most fortunate one from an economic standpoint, but is chosen because: (1.) The stone was quarried at Mansfield for several years and is known to some extent in the markets by that name. (2.) There is a typical and rather extensive exposure of the stone there. (3.) There is no other sandstone at that place with which it need be confused.‡

---

*The details of the stratigraphy of the Coal Measures will, no doubt, be worked out in connection with the economic report on coal, as the coal beds are the most valuable of the natural products of this area.

†Only the general properties of the sandstone are given in this chapter. The specific characters relating to the stone at the different localities will be found in the following chapter. The description of other stones, as the Portland, Cannelton, etc., will be found in the following chapters.

‡Other sandstone belonging to the productive Coal Measures outcrops west and northwest of Mansfield, but there is no other at or close to the village.

The same bed of sandstone is referred to in the former state geological reports as the Conglomerate, or sometimes as the Millstone grit. The objection to using either of these terms is that a lithologic term in itself does not properly designate a geologic formation, and even if it did it would not be appropriate in this case, as but a small per cent. of this formation is conglomerate, and a much smaller per cent. is good millstone grit. It might properly be termed the Mansfield sandstone and conglomerate, as the formation contains conglomerate in many places. But if only one term is used it is more properly designated a sandstone, as there is probably more than ten times as much sandstone as conglomerate, and the use of the geographic term definitely fixes the horizon.*

Geologic position.—The Mansfield sandstone lies at the base of the Coal Measures, unconformably upon the Lower Carboniferous limestone, or in the absence of the limestone on Lower Carboniferous sandstone or shale. There is thus a double delimitation below (1) the unconformity which is shown in many places by erosion channels and basal conglomerate, or both; (2) the Lower Carboniferous series with which it can rarely be confused on account of the sharp distinction in lithologic character. It is overlain by a series of shales, sandstones, and coal beds, in some places conformably, in others unconformably, and in general there need be little doubt about the vertical extent of the Mansfield sandstone, as where typically developed it is distinguished by its coarse-grained texture, massive structure, patches of quartz conglomerate, false bedding, and iron secretions. However, there are instances where the correlation is uncertain, as in some localities there is no massive sandstone at this horizon, but shaly sandstone and shales immediately overlie the Lower Carboniferous limestone where, in the absence of fossils, or of a thorough study of the overlying Coal Measures it is not possible to always determine whether these thinly laminated strata are correlative of the Mansfield sandstone, or whether that formation is absent entirely. If the Mansfield stone were always coarse-grained and massive the difficulty would be lessened, but in some places the massive sandstone is accompanied by thinly laminated sandstone and shale, which belong to the same period of deposition.

On the accompanying map sheets all the sandstone occurring at the horizon of the Mansfield sandstone is classed provisionally as Mansfield if there is no stratigraphic evidence that it belongs to a higher horizon.†

Varieties of Mansfield sandstone.—There are a great many varieties of the Mansfield sandstone in both color and texture. In color it ranges

---

*Sandstone is the broader term of the two. While the distinction between the two is mainly on the size of the particles, conglomerates are composed essentially of water-worn or rounded materials, while the sand grains may be either rounded or angular, and in the finer grained stones are almost universally angular.

† It is possible that some of the thinly laminated sandstone in the area south of Greencastle, and in some other localities along the eastern border of the formation, may be of more recent formation than the Mansfield, but the field work was not sufficiently detailed to establish that fact.

from nearly white through various shades of gray, yellow and red, to dark brown, yet they may all be divided into two general classes; (1) red or brown stone; (2) yellow and gray, with more or less variegated stone in both classes.

1. The *red* color in sandstone is caused either (1) by the grains themselves being red or (2) by a red cement where the grains themselves may be white or colorless, and coated with a more or less thin film of red coloring matter, which may be the cement wholly or in part. Stones of the second class are the more common, and in this class are the brownstones of Indiana.

The coloring matter of the Indiana brownstone is composed of iron oxides, which chemical analyses show to be present in quantities varying from two or three per cent. to nearly 23 per cent. The microscope shows the presence of the anhydrous red hematite accompanied by small quantities of the hydrous yellow and brown oxide. It occurs sometimes in a finely granular condition, sometimes as an impalpable powder in which the separate grains are not distinguishable under the microscope, and in places it is partly crystalline, showing crystal faces three one-hundredths of a millimeter in length.

There are many shades of the red and brown colors, one of the most common being a deep red-brown with a faint purple tinge suggestive of manganese, and having a faint steel lustre in places. It is a handsome and desirable building stone. Another common shade is a lighter red than the preceding, the lighter color being due partly to the greater abundance of the small white granular quartz particles and partly to a thinner coating of the iron oxide on the quartz grains. It is a handsomer stone than the first variety, but not so abundant. Another shade rather abundant at the Mansfield and the St. Anthony quarries has a nearly walnut brown body, with light particles. It is not so handsome as either of the preceding. Another less common variety, which has been called a "flea-bitten fawn skin," consists of a light brown body with light gray spots about the size of one's finger tip. The stone near Green Hill is a light red, a little paler than a cherry. It is the clearest red of any sandstone of the State that occurs in large quantities, and is in no sense a brownstone. The color is uniform over a considerable area. The lighter color is due to the iron oxide occurring in a less quantity, forming but a slight film on the white quartz grains.

There are several other varieties, some lighter, some darker, that occur for the most part in quantities too small to have any economic value. There is a banded variety that occurs in considerable quantities at Mansfield and elsewhere, which is made up of lighter and darker bands an inch or more in width and running at an angle of about 30 degrees to the horizontal, and following apparently the lines of false bedding of the rock. While beautiful in hand specimens, it would be out of place in walls, nor does it occur in sufficient quantities to be used alone for building.

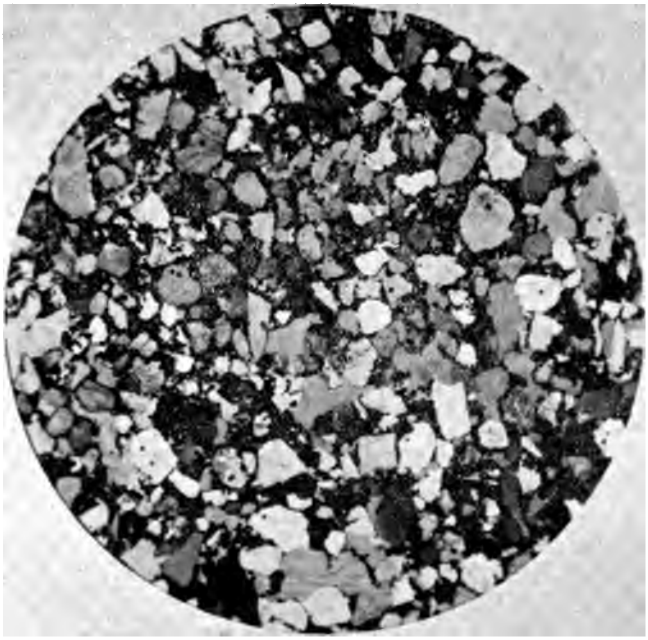
In all the numerous specimens examined, the color is due to the iron oxide in the cement and not in the grains themselves, which are white or transparent when removed from the cement. There are two possible sources for the iron oxide in the sandstone; (1) as sediment deposited at the same time as the sand; (2) carried in by infiltrating waters subsequent to the deposition of the sand. The evidence in favor of the second process is (1) in many places the color grades into gray along very irregular wavy lines which are far from horizontal; (2) the lines of banding follow the lines of false bedding along which the infiltrating waters naturally flow; (3) the iron blisters are evidently ferruginized pebbles [see further under texture], and (4) the patchy occurrence of the sandstone. However, it must be admitted that all these conditions are explained by the first hypothesis if we admit a secondary alteration of the iron by infiltrating waters.

It is possible that in either case the iron might first have been deposited in some other form, such as the sulphide or carbonate and subsequently oxidized, but there appears to be no direct evidence in support of this view.* Some of the phenomena can be accounted for only on the theory of infiltrating waters, and if some of the iron oxide was deposited contemporaneous with the sand it has been modified to some extent by the penetrating waters. Nor is it a surface phenomenon, but the interior of the beds is as deeply colored as the exterior.

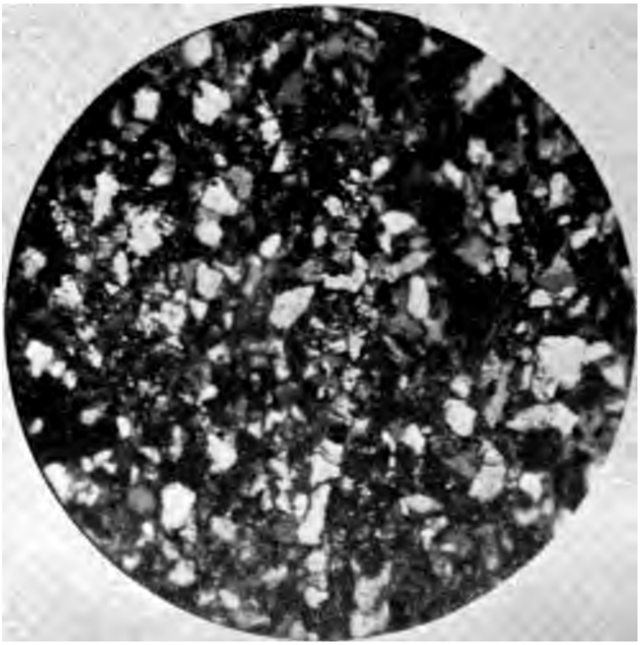
From an economic standpoint the greatest objection to the red or brown stone is that the color is nowhere uniform throughout the bed. In some places the variegations are so abundant that stone of a uniform color cannot be obtained in sizes suitable for building. In other places one color or shade will prevail for six or eight feet where it will give way to another shade through a like thickness, and by careful selection stone of different shades can be separated and abundance of any one color can be obtained. This can be done more economically in the saw-mill than elsewhere by setting the saws to run between the colors. It would necessitate the quarrying of a great deal of stone to keep up the supply of the color that happened to be the most popular.

2. The yellow, buff, and gray Mansfield sandstone is more abundant than the brownstone. The coloring matter in these varieties is the hydrous iron oxide, and in nearly all cases there is a less per cent. of the iron than in the red and brown stone. Some of the lighter colored, nearly white sandstones are almost entirely free from iron. As a rule these lighter colored rocks are softer and more friable than the darker brown stones. Yet this is not always the case, as one of the hardest and

* Dr. J. W. Dawson argues that in the red beds of Nova Scotia the red oxide is derived from decomposed iron pyrites. Q. J. G. S. Vol. V, p. 25.



No. 1.



No. 2.

MICROPHOTOGRAPHS.

No. 1. *MANSFIELD SANDSTONE*, MANSFIELD, INDIANA. (Magnified 25 diameters.)
No. 2. *RIVERSIDE SANDSTONE*, RIVERSIDE, INDIANA. (Magnified 70 diameters.)

least friable sandstones in the whole area is nearly white in color. The light gray colored stone is less common than the buff and yellow. The deeper colored ones in many places have iron secretions, either the iron kidneys or segregated veins, the iron secretions frequently gathering along the lines of false bedding.

Structure.—The Mansfield sandstone in most places is a medium to coarse-grained sandstone occurring in a massive bed varying from a few feet to more than 100 feet in thickness. In some places the massive seamless stone is accompanied by a few feet of thinly stratified sandstone, in others by a coarse conglomerate, and in many places by a black shale, fire-clay, and coal. In many places it is characterized by false bedding and iron secretions. Characteristic features of the bed are its massiveness, the prevalence of false bedding, and the occurrence of coarse conglomerate. While common these are not constant phenomena.

The conglomerate occurs in irregular patches varying from a few inches to several feet in thickness, sometimes at the bottom of the sandstone, sometimes at varying levels through the bed. In rare instances there are isolated quartz pebbles scattered through the sandstone, but the more common occurrence is the accumulation of the pebbles in masses with very little, sometimes no intermingled sand.

The false bedding planes in most instances dip 25 to 30 degrees from the horizontal. In general at any one locality these lines of false bedding all dip in the same direction, yet in some instances the false bedding in one layer is dipping directly opposite to that in an adjoining layer. The false bedding is caused by swiftly moving water carrying a heavy load of coarse material, meeting quieter and deeper water, where the load is suddenly dropped. Such a condition is found at the place where a river empties into the sea or lake, in the eddies and pools along a river, and in ocean currents where they sweep over an uneven bottom. Infiltrating waters frequently follow along these lines of false bedding, carrying more or less iron and giving the stone a banded structure.

Texture.—The texture of the Mansfield sandstone through about nine-tenths of the bed is comparatively uniform, but the other one-tenth is quite variable. The mass of the stone consists of a rather coarse but evenly granular quartz sandstone, associated with patches of conglomerate, varying from half an inch to eight or ten feet in thickness, and the pebbles varying from the size of a grain of wheat to those as large as one's head. There is also intercalary shale, shaly stones, fire-clay, coal, and iron ore. The conglomerate pebbles are sometimes of chert from the underlying cherty limestones; in such cases the pebbles are large and sometimes subangular, generally occurring at the base of the sandstone, but not always so. More commonly the pebbles consist of well water-worn quartz and occur either in closely aggregated masses or loosely and irregularly scattered through the body of the sandstone. The conglomerate is more or less local in its occurrence and while it rarely forms a large part of the bed, over many extensive areas it does not occur at all. It apparently forms much less than 10 per cent., probably not more than five per cent., of the whole formation.

Aside from the conglomerate and shaly patches the sandstone is comparatively uniform in grain and would ordinarily be termed a coarse grained sandstone, yet, according to Orth's classification (see p. 191) it would be termed medium fine-grained sandstone. The following measurements were made in the microscope with a micrometer scale on an average specimen of the stone at each locality by measuring 10 to 20 contiguous grains and taking the average. The largest grain is the largest in the thin section examined, not necessarily the largest in the rock.

Size of grains in the Mansfield sandstone.

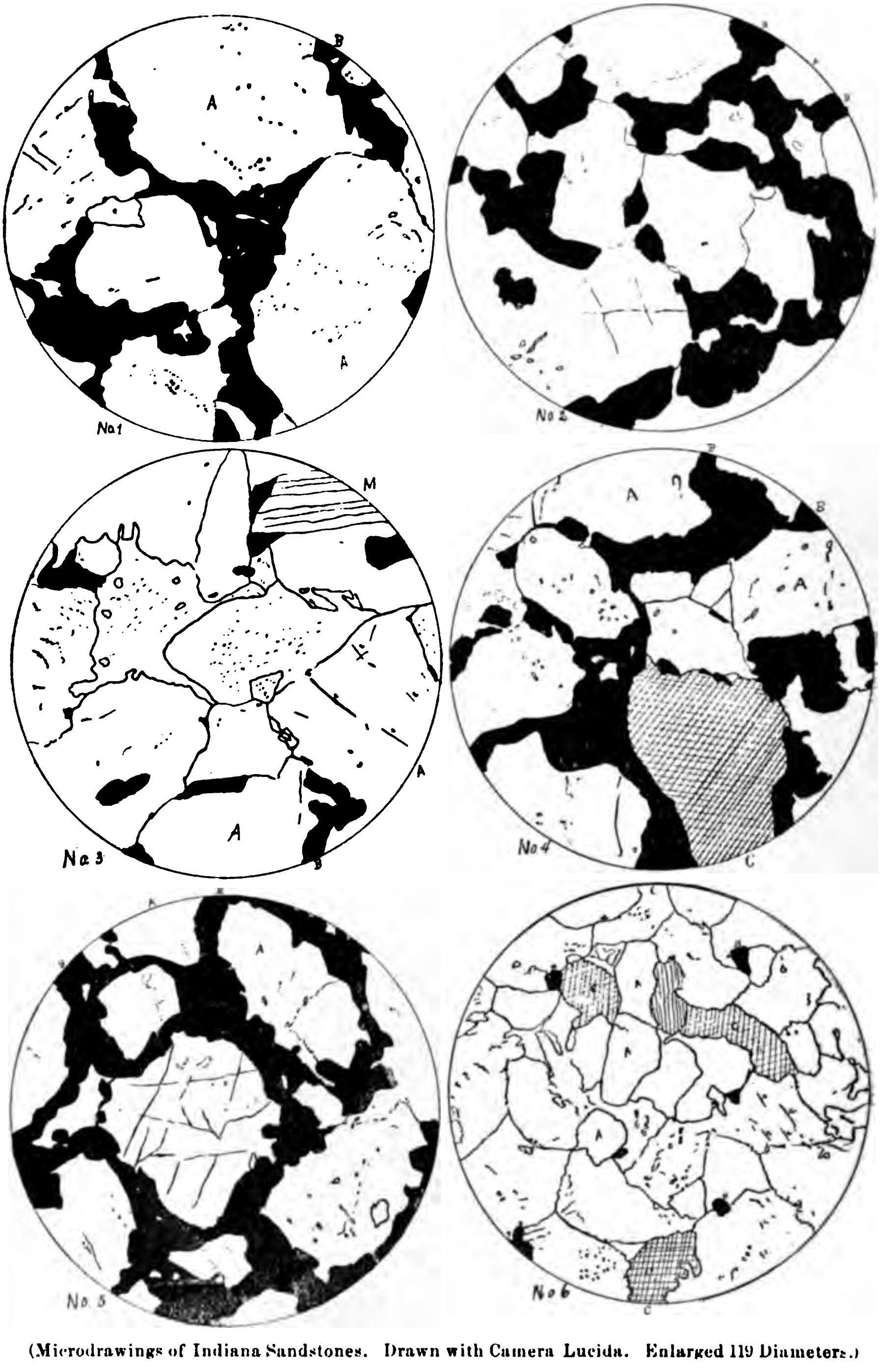
		Millimeters.	Inches.
Mansfield	Average	0.29	0.0114
	Largest	0.65	0.0256
Portland Mills	Average	0.34	0.0134
	Largest	0.60	0.0218
Bloomfield*	Average	0.28	0.011
	Largest	0.45	0.017
St. Anthony*	Average	0.32	0.0126
	Largest	0.48	0.0189
Williamsport	Average	0.19	0.0075
	Largest	0.32	0.0126
Cromwell, Conn. (2)	Average	0.25	0.0098
	Largest	0.60	0.0218

All of the specimens are brownstone but the Williamsport one, which is buff colored.

In general the grains are angular, yet in some specimens the larger grains are rounded or subangular. The angularity of the grains has much more to do with the strength of the stone than is commonly supposed, as the angular grains fit more closely together and more closely interlock, and with the same amount of cement will form a stronger stone than a similar stone with round grains, just as a wall of uncoursed rubble is stronger than one of cobble stones. It will be noticed on comparing the different sections on the accompanying figures (plates 11, 12, and 14) that the grains are more rounded in the brownstones than in any of the others, but it will be noticed as well that the brownstones have more cement than the others, except the brown or red stone from near Green Hill, which has less, and which is also one of the most friable stones of the area. Of course much depends upon the character of the cement,

*The Bloomfield and St. Anthony stones are classed provisionally with the Mansfield, but have not yet been proven to be of the same age.

(2) The Connecticut stone is given for comparison.



(Microdrawings of Indiana Sandstones. Drawn with Camera Lucida. Enlarged 119 Diameters.)

No. 1. MANSFIELD.
No. 2. PORTLAND MILLS.
No. 3. GREENHILL.
No. 4. ST. ANTHONY.
No. 5. BLOOMFIELD.
No. 6. CANNELTON.

A—Quartz.
B—Iron oxide.
C—Quartz aggregate (chert?)

but it can be easily seen that a stone with closely interlocking angular grains like no. 6 on plate 12 will require but little cement to make it comparatively rigid, while abundance of good cement is necessary to give strength to stone like no. 1 on the same plate. It should be noticed, however, that the rounded grains are nearly all more or less etched or notched, thus giving an anchorage to the cement, and where the cement of good quality is present, as it is in the brownstones figured, the stone is sufficiently rigid for most purposes. The reason for rounded grains in some and none in others is due to (1) the greater size of the grains, as grains below a certain size are never rounded, and (2) probably to transportation over greater distance or longer or more violent beach action.

Some of the coarse-grained yellow and gray sandstones, where the cementing material is much less than in the brownstones, are found to be much more friable and porous than either the brownstones or the fine-grained sandstones, which have no more cement but have more angular grains.

In most of the Mansfield stone, but most conspicuous in the darker colored brownstones, are small yellow or light gray specks about the size of the single quartz grains, and to the naked eye looking like a white amorphous powder of some kind. Under the microscope they are found to be composed of finely crystalline cryptocrystalline granular quartz, and are thought to be grains of chert. The reasons for thinking so are (1) the color and general appearance are the same; (2) they appear the same under the microscope; (3) a partial gradation from the chert conglomerate, where the chert character of the pebbles is plainly shown to the naked eye, to the sandstone, where the resemblance is microscopic; (4) there is apparently no other source for the material unless it be deposited by siliceous waters, in which case the spots should not be almost universally isolated, but would be for the most part connected by finer veins of similar material, and would form a cement instead of grains.

Chemical composition of Mansfield sandstone.—The accompanying table shows partial chemical analyses of Mansfield stone from a number of localities, all made by the hydrochloric acid process. No sodium carbonate analysis was made, but in most instances it would show but little difference from that given, as the insoluble part, as shown by microscopic examination, is nearly all quartz. In a few places there are sufficient mica and microlite inclusions in the quartz to reduce the actual silica percentage possibly two or three per cent. below that of the insoluble residue. In some instances, as far as shown by the microscopic examination, the difference would be less than this, so that the insoluble residue percentage is practically very near that of the silica. The water of crystallization and organic matter were not determined; they would in most instances bring the percentage up to 100. There are traces of magnesia and alkali, but in inappreciable quantities. The carbonic acid as given in the table was found by computation, by considering all the lime as carbonate.

Chemical analyses of Mansfield sandstone.

No.	LOCALITY.	Color of Stone.	Color of Insoluble Residue.	Insoluble in H Cl	Alumina Al_2O_3	Iron Oxide Fe_2O_3	Lime Ca O	CO_2	TOTAL.
1	Mansfield	Brown.	White.	92.16	....	6.29	0.05	0.04	98.63
2	Portland Mills	"	"	(2)	2.58	19.39	....	.25	....
3	Judson	"	"	93.21	.51	4.91	.12	.095	98.75
4	Hillsboro	"	"	91.65	.56	6.60	.12	.095	98.93
5	Fountain	"	"	91 66	.60	6.44	.05	.04	98.72
6	Bloomfield	"	"	85.29	.19	11.82	.06	.05	97.43
7	St. Anthony	"	"	88.41	.63	8.40	.13	.10	97.57
8	Green Hill	Red.	"	98.73	.28	.36	.03	.024	99.40
9	Williamsport	Buff.	"	98.57	.05	.65	.02	.016	99.29
10	Fern	"	"	(2)	.30	1.03	....	....	....
11	Cromwell, Conn.	Brown.	"	70.84	13.15	2.48	3.09	9.73 Alk	100.00 (4)

(2) Made by Prof. P. S. Baker, DePauw University.

(4) Furnished by the New England Brownstone Co. All the other analyses were made for the survey by H. H. Ballard, at Rose Polytechnic Institute.

It will thus be seen that the stone consists essentially of insoluble material, mostly quartz, and iron oxide, both very durable substances.

Mineralogical composition.—The brownstones consist almost entirely of quartz grains, chert grains, and iron oxides.

The quartz contains microlites of rutile, zircon, and apatite, none of which are abundant, the last one, apatite, being exceedingly rare. The rutile occurs in exceedingly fine, slender needles, that are only visible when highly magnified. Only a small per cent., probably less than 10, of all the quartz grains contains rutile. The zircon occurs in very small irregular, isolated, widely scattered crystals.

In many localities muscovite is present in scattered flakes, but in no place abundant, as it is in some of the overlying Coal Measure sandstone.

No feldspar was observed in any of the brownstone examined, but some of the gray and buff stones, noticeably that at Williamsport, shows the presence of both plagioclase and microcline, the latter in greater quantity, yet neither one sufficiently abundant to have any appreciable effect on the durability of the rock.

The iron oxides forming the cement consist of both the hydrous (limonite) and the anhydrous (hematite) forms. The presence of both oxides is shown by the colors, but the examination was not sufficiently minute to show whether other hydrous oxides, as goethite, turgite, etc., were present with the limonite or not.

Strength of the Mansfield sandstone.—Sandstones, with the exception of the quartzitic ones, are, as a rule, much weaker than the other common building stones, such as granite, syenite, limestone, marble, etc., weaker both in resisting crushing force and in transverse strength. The Mansfield sandstone is probably no exception to the rule as indicated by the result of the test given below. However, since in our largest structures building stones are rarely if ever loaded to one-sixth or even one-tenth of their ultimate strength, this in itself need not be and is not any drawback to the use of sandstone for building purposes.

There was not a sufficient number of tests made on the strength of this stone to give a fair or reliable average.* The sample from St. Anthony quarry was tested for the survey at the Rose Polytechnic Institute,† and showed a strength of 12,000 pounds for a two-inch cube, equal to 3,000 pounds per square inch. Samples of the Berea, Ohio, sandstone, furnished by the Cleveland Stone Company, tested at the same time, under the same conditions showed a strength of 11,200 pounds and 12,767 pounds respectively. Samples of the Bedford oolitic limestone tested at the same time gave 7,125 pounds per square inch.

The stone is in most places quite soft and friable when first removed from the quarry, but hardens and becomes much stronger when seasoned. No experiments were made to illustrate the difference in strength between the green and the seasoned stone, but there would be quite a marked difference. So soft and friable does the stone appear that many of the citizens refuse to use it in the foundations of their buildings for fear it is not strong enough to support them. This is more commonly the case along the eastern border of the sandstone area where it occurs in the same locality as the compact blue Lower Carboniferous limestone, which in contrast with the softer sandstone makes the latter appear really softer than it is. No instance is recorded of any of it ever crushing under any structure. If the stone is properly quarried and seasoned it will be found on trial to be sufficiently strong to withstand any crushing force to which it might be subjected in any structure; ‡ not only that, but it will prove to be stronger after ten years' exposure than at the time it was placed in the wall.

Fire tests.—As with the others, the fire tests are too meager to have any decisive value and are mentioned as only indicative of the possibilities. Samples from the quarry at St. Anthony were tested in the laboratory at Terre Haute with the following results: (1) Cold stone placed in melted lead and allowed to remain until lead would melt on its surface, then placed in the air to cool. Cracks appeared at corners as soon as cooling began. (2) The cold stone in a covered crucible placed in the

* The survey offered to have tests made and publish the results if the quarrymen would furnish the samples and bear the slight expense connected therewith; while others promised to do so only one furnished the samples in time to have the tests made for this report.

† For comparison with other sandstones see tables in the last chapter.

‡ In a wall 300 feet high, higher than any that will probably ever be constructed in Indiana, the crushing force from the weight of the wall alone would not exceed 350 pounds per square inch, and the added weight from roof, floors, and contents, would probably never raise this beyond 450 pounds, so that at 3,000 pounds, which will prove to be below the average, the margin is nearly nine to one, and in ordinary uses it will not exceed fifteen or twenty to one.

fire cracked at corner before the lead would melt. (3) The stone heated to temperature of melted lead thrust into water cracked in several places. Similar experiments at the same time on Riverside sandstone and the Berea, Ohio, stone gave practically the same results.

The writer heated to redness a number of small samples from different localities in the flame of a bunsen burner and permitted some to cool in air and some were thrown into cold water. None cracked on heating, about 50 per cent. cracked on cooling and all were more friable and much softer after cooling as though the cement had in a large measure been destroyed.

The tests would, therefore, indicate that the stone, from certain localities at least, would rank very low in its power to resist high temperature. In many places this stone has been used in chimneys and in sugar furnaces by the citizens, and in most instances appears to stand the flames without injury. Experiments elsewhere have shown that as a class sandstones rank below other building stones in this respect.

Absorption tests on Mansfield sandstones.—Absorption tests were made on only two samples, both from St. Anthony. The specimens were weighed, put in water for 25 hours and reweighed; the ratio of absorption was 8.6 and 7 per cent., which, as may be seen by referring to the tables at the end, is above the average. Berea, Ohio, stone, tested at the same time, gave 4.9 and 5 per cent. While there can be little doubt but that the ratio of absorption for the Mansfield stone is high, probably above the average, it may not be so high as that indicated by the figures.

Durability of the Mansfield sandstone.—The Mansfield sandstone is one of the most durable rocks in the State of Indiana, or for that matter in the United States. This statement will be at once disputed by the casual observer or by persons living in limestone regions, but not by a geologist after field examination. The ordinary observer will not believe that the soft crumbling sandstone is more durable than the hard, compact limestone, which in comparison is so difficult to cut and break.

In so far as resistance to crushing is an evidence of durability, as argued by some writers, the Mansfield stone is lacking and would rank among the lowest. However, it is well known to even the most casual observer that this evidence in itself is valueless, as the clay ironstone and the black limestone of this area would have a crushing strength many times that of the Mansfield stone. Yet when exposed under the same conditions, long before the sandstone would be in the least affected, except to become harder, the black limestone would have crumbled to fragments.

Evidence of durability of Mansfield sandstone from composition.—The evidence from the chemical and mineralogical composition of the sandstone is suggestive of a stone of great durability. The quartz grains are practically indestructible, and the ferric oxide under the conditions to which it would be subject in ordinary structures is one of the most enduring of minerals. In its composition the Mansfield brownstone is superior to the Triassic brownstones, most of which have a high per cent. of alumina.

Dr. Hunt was one of the first to state that, other things being equal, the closer the texture and finer the grain the more durable the rock, and many succeeding writers have overlooked the clause *other things being equal.* Other things are not equal in this case, and in many others, as the Mansfield stone is probably coarser grained and probably as porous as any other rock in the State, yet it is one of the most durable. This is not because of its coarse open texture, but in spite of it.

Condition of the outcrop as an evidence of durability.—To the experienced geologist there is no evidence so satisfactory or convincing in regard to the durability of a rock as a study of its natural outcrops. This, however, like the other evidence, must be taken with intelligence, and is not governed by any fixed rules. In the case of the Mansfield sandstone, the field observations all support the statement in regard to the great durability of the rock, especially as compared with the associated rocks. The characteristic occurrence of the stone is in bold or overhanging cliffs, with frequently many large angular boulders scattered along the base. This is caused by the disintegration and erosion of the underlying rock at a more rapid rate than the sandstone, and when the overhanging cliff projects so far that the weight of the overhanging mass exceeds the cohesive strength of the stone it breaks off and lies in boulders along the base of the bluff then exposed to the weathering agencies on all sides. Yet after centuries of exposure these boulders occur with firm, even surfaces, and sharp angles with scarcely a trace of disintegrated material surrounding them. Some of these dislocated masses are such conspicuous features as to have acquired locally the name of "fallen rock." Such a fall took place on Shawnee creek, near Rob Roy, but two years ago, where several hundred tons of rock broke away from the parent ledge producing a jar equal to a miniature earthquake. Nearly all the exposures of this rock along the watercourses and elsewhere indicate a stone of remarkable durability.

Glacial striæ an evidence of durability.—Another convincing evidence of the durability of the Mansfield sandstone is the good state of preservation of the glacial striæ on its surface in many places. The rock in such instances has withstood the disintegrating forces perfectly since the advance of the glacier many thousands of years ago. In several places these striæ were observed in the watercourses where they have not only withstood the weathering agencies, but for some years at least have withstood the erosive action of the streams. A list of the localities where these markings are well preserved, are given below.

List of localities showing glacial striæ on the Mansfield sandstone, with direction of same.—

1. 19 N., 6 W., sec. 8, S. 20° W.
2. 17 N., 6 W., sec. 19, S. 45° W.
3. 17 N., 7 W., sec. 27, S. E. ¼, S. 37° E.
4. 17 N., 7 W., sec. 27, S. W. ¼, S. 37° E.
5. 16 N., 6 W., sec. 19, S. 25° W.
6. 16 N., 5 W., sec. 32, S. 45° W.
7. 15 N., 5 W., sec. 30, N. W. ¼ of S. W. ¼, S. 25° W.
8. 15 N., 5 W., sec. 30, N. W. ¼ of S. E. ¼, S. 25° W.
9. 14 N., 5 W., sec. 8, S. 25° W.
10. 14 N., 6 W., sec. 5, S. 45° E.

Evidence of the durability of the Mansfield stone from old structures.—The commonwealth of Indiana is too young to have any very old buildings from which to study the durability of its building stones, as can be done so profitably with other stone in many continental countries. Yet there are buildings of Mansfield sandstone in Indiana, now in a good state of preservation, that were constructed many years before some of their neighbors built of other stone that are now showing evidence of decay.

The Martindale house, a few miles southeast of Pine Village, Warren county, was built 40 or more years ago.* It is constructed of red sandstone from the quarry south of Greenhill, and quarried by hand, with the liberal use of gunpowder (enough to injure any good stone), yet it appears uninjured by its exposure, not even discolored. The stone at the quarry from which this stone was obtained is more friable than that at almost any other locality in the entire area.

The Barney Brown house, at Rob Roy, Fountain county, is said to have been built 50 or 60 years ago, and is yet uninjured, so far as the stone is concerned, except a slight discoloration. A poor quality of mortar was used, as it has been removed to such an extent as to appear at present as though the stone was laid up without mortar. There was likewise a poor selection of colors, which does not produce a happy effect, but is not wholly the fault of the stone. In both the above houses there is a sad lack of architectural skill, but both are evidence of the capability of the stone to withstand the disintegrating forces. The stone in both houses and in others in different localities, is now much harder than that in the quarry from which it was obtained.

Along the Wabash Railway, in Warren and Fountain counties, built in 1856, Mansfield sandstone was used in some of the bridges and culverts and was found to stand so well that in most of the new culverts constructed during the last few years the Mansfield stone has been used. The stone has been used in many wagon bridges throughout the area and where any

* The exact date could not be ascertained further than it was a number of years before the war.

care has been observed in the selection and the seasoning of the stone it has been entirely satisfactory. It might have been used with equal satisfaction at many other places where limestone has been used at greater expense, because it was thought the sandstone was too soft to stand the weather.

The writer has no hesitancy in recommending the Mansfield sandstone from the standpoint of durability alone, despite its softness, provided (1) that ordinary intelligence is used in its selection, as there is, of course, much poor stone in any formation, and (2) that it is quarried in proper season and without the use of powder or other explosives.

Adaptability of the Mansfield sandstone.—The Mansfield sandstone is adapted to rock masonry of all kinds where it will not be subject to great transverse strain, violent abrasion or require a smoothly finished or delicately carved surface. It is well adapted for use in stone buildings, either wholly or as stone fronts or for water tables, sills, cornices, pillars, etc., but if used for lintels or other purposes where it will be subject to transverse strain extra thickness should be used, or, it should be protected from cross strain by overarching or other means. It will furnish valuable bridge stone if proper precautions are taken in construction. The ground course, if exposed above low water mark, should be protected by an external coating of cement, and where the piers or abutments are exposed to an extra rapid current or one carrying much suspended matter, it should be protected by riprap or broken stone, as in fact should be done with any stone.

Distribution of the Mansfield sandstone.—As already stated the area over which the stone extends forms a belt of varying width, running in an east-of-south direction from Warren county on the north to the Ohio river in Perry and Crawford counties in the south. The stone outcrops in Warren, Fountain, Montgomery, Parke, Putnam, Clay, Owen, Greene, Monroe (?), Martin, Orange, Crawford, Dubois, and Perry counties. In the first five of these counties and parts of Clay and Owen the outcrop has been mapped in detail and is shown on the accompanying two map sheets. The approximate location of the remainder of the area may be seen on the sketch map at the beginning of this report. No detailed work has been done on any part of this approximate area so far as known, except in Orange and a part of Martin and Dubois counties by E. M. Kindle and shown on the map sheet accompanying his report on the whetstones in this volume, and in Monroe county by Mr. C. E. Siebenthal in a map as yet unpublished.

The brown stone and the buff are not distinguished on the map. The brownstone occurs in considerable thickness at the following localities:*

1. In sections 31 and 32 (23 N., 6 W.), two miles southwest of Greenhill in Warren county, where it is more properly red than brown, and

* For particulars on each of these localities consult the index.

has been quarried for building stone and for bridges; quarry not now in operation.

2. At Fountain (Portland) in Fountain county, where it has been quarried in small quantities along with the gray and buff.

3. At Hillsboro in Fountain county, where it has been quarried to considerable extent and shipped to Chicago and elsewhere.

4. At the Narrows, on Sugar Mill creek a mile and a half southwest of Wallace, Fountain county, where no use has been made of it.

5. On Mr. Milligan's place, near Russell's old mill, in section 15 (17 N., 7 W.), in Parke county, where it has been slightly exploited, but none shipped.

6. About a mile southeast of Guion, Parke county, where a limited quantity was quarried several years ago.

7. About two miles south of Judson, where a quarry has been open on a small scale for two years, but has accomplished very little.

8. At Portland Mills, Parke and Putnam counties, a quarry was opened this year (1895) on a rather large scale and the company plans to take out stone in large quantities.

9. At Mansfield, Parke county, a quarry was in operation for several years and several hundred car loads of stone shipped away.

10. On Mr. Pruitt's place, a mile and a half northeast of Mansfield, the brownstone occurs in limited quantities and has been quarried for local use.

11. On Little Rocky Fork near Fallen Rock, about three miles southeast of Mansfield, brownstone of superior quality is exposed. It occurs over a considerable area, but of commercial value in only a few places; it has never been worked.

12. About two miles east of Bloomfield, Greene county, is a deposit of brownstone of superior quality that has not been worked, but will be important in future time.

13. Near St. Anthony, Dubois county, is a deposit of brownstone not so thick as that farther north, but of good quality and extensively worked.

14. Between Jasper and Knoxville, in Dubois county, is a more or less extensive deposit of brownstone that has not been developed. Other occurrences of similar stone are reported between this exposure and the quarry at St. Anthony.

Brownstone of inferior quality occurs a few miles southeast of French Lick, in Orange county, and at a few other points in Orange and Martin counties, and probably in other localities that were not explored.

It will be observed that the brownstone does not form a continuous bed over the whole area, but occurs in isolated areas variable in size and extent, and surrounded by the gray and buff stone with which it is sometimes interstratified.

The buff and gray sandstone occurs over the entire area designated on the maps, concealed in many places by the glacial drift in the north part of the area and by the accumulated soil in the south part of the area, but outcropping in areas of greater or less extent along nearly all the watercourses.

While it has been quarried for local use in a great many places, it has been worked in large quantities in only two localities—Williamsport and Attica. At Williamsport the quarry was opened many years ago, but the working of it on a large scale is of recent date.

In the vicinity of Attica there are several large quarry openings on both sides of the Wabash river, only two of which are now in active operation, both on the north side of the river in Warren county.

CHAPTER IV.

LOCAL DETAILS OF THE GEOLOGIC FEATURES AND THE DISTRIBUTION OF THE SANDSTONE.

Eel River Basin.*

Eel river is a tributary of the north prong of White river and with its tributaries drains nearly all of Putnam and Clay counties and parts of Owen and Greene counties. While considerable sandstone occurs in places along the lower course of the stream, only such portion of the valley as lies north of town line 12 N. was examined and is described in this report.

Jordan Creek.—Many terminal ravines of Jordan creek extend into 12 N., 4 W. and 5 W., but they are mostly in a drift-covered area, the sandstone so far as observed outcropping only in the southwest quarter of Sec. 33 (12 N., 4 W.), Owen county. Just south of the township line in a ravine in the northeast quarter of Sec. 5 and the northwest quarter of Sec. 4 (11 N., 4 W.), is an outcrop of massive sandstone, 30 to 35 feet exposed. Some of the stone is light gray, but most of it is yellow, and some variegated yellow and gray. The stone is ferruginous in places with some cross-bedding, but much of it is even-grained, comparatively free from iron and would furnish good building stone, especially bridge and foundation stone for local use. The most promising outcrop for quarrying is in a small secondary ravine from the south in the northeast quarter of Sec. 5 (11 N., 4 W.), where the water has cut

* The term Eel river is sometimes applied to what is locally known as Mill creek and sometimes to Walnut creek. In this report we follow the most common local usage, applying the name to the stream formed by the confluence of Mill creek and Walnut creek, giving the local names to the tributaries above this point.

a narrow gorge 10 to 12 feet wide through the rock in which the sandstone is exposed in a bold cliff 25 to 30 feet high on each side, with little or no covering for several yards back from the face of the cliff, thus being in an admirable position for quarrying at comparatively no expense for stripping.

The sandstone lies unconformably on a compact blue limestone, which outcrops 20 yards north of the sandstone gorge, and up the main branch from the east into the N. W. quarter of Sec. 4 (11 N., 4 W.), in which quarter there is a bright red sandstone, which appears to occur in patches of considerable extent in the yellow and gray sandstone, but not in sufficient quantities to justify quarrying it alone.

Down Jordan creek to the south and west, bluffs of yellow and gray sandstone of considerable extent are reported, but were not examined.

Eel River below Croy's Creek.—While no valuable dimension stone occurs in the Eel river basin between Croy's creek and town line 12 N., sandstone suitable for bridges and foundations outcrops in several places and has been quarried to a small extent at three different points.

A small quantity of inferior sandstone has been quarried on Mr. McIntosh's farm in 12 N., 5 W., Sec. 31, the S. E. quarter of the N. W. quarter.

On Mrs. Nancy Byer's place, in the N. W. quarter of the S. E. quarter of the same section, sandstone has been quarried for local use to a depth of six to eight feet. It has an even cleavage parallel to the bedding, and is comparatively uniform in grain and color, except where small leaf-like patches of dull brown occur in the buff to yellow body. The brown spots are spots of weakness. Stone from this place has been used in the bridge across Eel river in the S. W. quarter of Sec. 29 (12 N., 5 W.), and in smaller bridges and foundations in the neighborhood.

A ledge four to six feet thick of a similar sandstone is exposed east of the wagon road on the east side of the same 40 acres. A larger quarry is reported about half a mile south of the limits of our map, near the middle of Sec. 6 (11 N., 5 W.).

On the west side of Eel river below the Poland bridge, through the N. W. quarter of Sec. 32 (12 N., 5 W.) and the N. E. quarter of Sec. 31 is a cliff of coarse-grained yellow sandstone, 10 to 12 feet thick, containing conglomerate in places. While in some places it has a comparatively even grain and color in most places it is cross-grained and contains many iron blisters. As there is but very little covering and the rock is very durable it might be quarried to advantage for bridge stone at points where the cross-bedding is not too strongly marked.

At the bridge in the N. W. quarter of Sec. 32 (12 N., 5 W.) the sandstone is thin-bedded and associated with black and drab-colored shale. Above (north of) the bridge the shale is replaced in part by sandstone.

On W. B. Ringgo's farm in Sec. 20 (12 N., 5 W), the south side of the section, about midway between his house and the river, is a small outcrop of sandstone which is superior in quality to any of the sandstone described above but it is limited in quantity. The stone has a medium fine grain and a light gray color dotted with small brown spots. It is overlain by three to six feet of soil and drift, which thickens rapidly back from the face of the quarry, so that only a limited supply of stone could be obtained. Northeast of Mr. Ringgo's house, near the middle of Sec. 20, is an outcrop of massive yellow and gray sandstone that has been quarried for rip-rap along the river bank. It contains too much false bedding for dimension stone.

There is a small outcrop of very pyritiferous sandstone and black shale at Carpenter's mill, in the N. E. quarter Sec. 20 (12 N., 5 W.), which has no economic value but has been dug in several places in search of silver. Pyrite is abundant in many places at this horizon (the base of the Coal Measures), and especially so at this locality where it is associated with shale, sandstone, and a complex conglomerate. The rather uncommon appearance of the rocks, along with the metallic look of the pyrite, has suggested to some the possible occurrence of gold and silver. As a result considerable capital has been spent exploiting for precious metals at this and neighboring localities.

That there is a considerable bed of sandstone in this locality is shown by the well section at Mr. Ringgo's house on the south side of Sec. 20 (12 N., 5 W.), in which, after passing through 11 feet of sand and soil, the drill penetrated 51 feet into white sandstone without going through it. Part of the stone, possibly a large part judging from the surrounding outcrops, is pyritiferous, and the water in the well is so strong with the iron sulphate from the decomposed pyrite as to be unfit for household use.

On the east side of Eel river, between the mouth of Mill creek and town line 12 N., there is very little sandstone exposed, a wide bottom bordered by gentle drift slopes extending most of the way. There is a small outcrop of yellow sandstone and intercalary shale just north of the township line in the S. E. quarter of Sec. 33 (12 N., 5 W.), a little more than half a mile west of the brick church, where the stone has been quarried to some extent for use in foundations in Poland. Another small quarry from which foundation stone has been obtained is on the north side of the road a quarter of a mile west of Poland. In both places the stone is of inferior quality and in limited quantity.

Croy's Creek.—The Mansfield sandstone outcrops in a number of places along Croy's creek, but in no place does it have more than a local value, and in many places is not even suitable for foundations, as it contains much cross bedding, many iron secretions, and in places is shaly and crumbling.

There is an outcrop of thin-bedded white sandstone in the bed of the creek at the bridge near the mouth of the creek in the S. E. quarter of Sec. 17 (12 N. 5 W., Putnam county). A shaft sunk less than a quarter of a mile west of the bridge would indicate a considerable thickness of this stone (25 feet or more).

In a small tributary ravine from the west, just above the bridge, sandstone outcrops in considerable quantities. Near the mouth of the branch, on the south side of the road, sandstone has been quarried for bridges and foundations, and was used in the abutments of the bridge across Croy's creek, mentioned above. The exposure shows from four to six feet of coarse-grained ferruginous sandstone overlain and underlain by shale. The stone contains numerous iron secretions, and is not suitable for superstructures.

About 100 yards west of the old quarry opening is an outcrop of sandstone, drab and black shale, and conglomerate, that has been worked for several years in search of silver. Up the ravine, west of this opening, considerable sandstone is exposed, which is superior in quality to that described above. In one place, about a quarter of a mile above the "silver mine," is an outcrop of four to six feet of sandstone of a light yellowish red, of rather pleasing and durable color. It has a medium fine, even grain and would work easily, but has numerous weather seams on the exposure. The stone could not be obtained in commercial quantities unless the overlying yellow stone could be worked with profit at the same time, and even then the quarrying of it would be attended with some risk, as the color is subject to sudden changes.

Near this patch of red sandstone in the rock in the bottom of the creek is a kettle hole, known locally as the "crucible," 12 to 16 inches in diameter and five or six feet deep, which is formed by the eddying currents. About 100 yards west of the red sandstone the ravine has cut a narrow passage eight to ten feet deep through a bed of massive yellow to buff colored, coarse-grained sandstone, which might be used for bridges and foundations.

Near the middle of Sec. 17 (12 N., 5 W.), on the south side of Croy's creek, on the north-south road, is an outcrop of brown stone similar in color and texture to that at Mansfield, but of a loose, shelly structure. It is doubtful if good stone in commercial quantities could be obtained here, as it would require too much stripping to reach the solid stone. The brown stone is overlain by a pink-colored sandstone and underlain by yellow sandstone and shale.

In the S. W. quarter of Sec. 17 (12 N., 5 W.) on the road northwest of Mrs. McCullough's, is an outcrop of soft, crumbling sandstone, underlain by black shale and coal.

In the S. W. quarter of Sec. 9 (12 N., 5 W.) is an outcrop of 10 to 15 feet of massive yellow, cross-bedded sandstone which is too much cross-grained to work easily. Small exposures of sandstone along with a fissile black shale occur up this ravine farther north.

At the cross roads in the middle of the west side of Sec. 5 (12 N., 5 W.), and several places on the east side and S. E. quarter of the same section, soft, shelly sandstone is exposed, in some places yellow, in others brown, but all too shelly to have any commercial value. This sandstone belongs to a horizon above that of the Mansfield stone.

No outcrop of sandstone of even local importance was observed on Secs. 7 and 18 (12 N., 5 W.). On Mrs. Farrow's place, S. E. quarter of Sec. 1 (12 N., 6 W.), an outcrop of yellow sandstone that was quarried for local use twenty years or more ago. It is said to have been worked to a depth of eight or ten feet, but only three or four feet are exposed now. The deposit is too thin and the covering too heavy to permit an extensive use of the stone.

A small quarry of nice building stone is located on Mr. Inglehart's place, about a mile southwest of the above, in the N. E. quarter of Sec. 11 (12 N., 6 W.). It is over a low divide from Croy's creek in the Birch Creek valley. The stone is fine-grained, homogeneous, and light gray in color with faint shadowy yellow in places, and works easily to a smooth surface. It occurs in regular layers, ranging from two inches to 24 inches thick. The whole thickness that has been quarried is about four feet. It is overlain by three feet of soil and is said to be underlain by coal. This quarry has been in operation in a small way for thirty years or more. In 1895, 300 perch of stone were removed and sold at $1 per perch. It is said to withstand fire so well that stone was hauled from here to Knightsville for use in the iron furnace in operation there years ago.

On Mr. Hadden's place in the N. W. quarter of Sec. 36 (13 N., 6 W.), on the north side of the small ravine southeast of the schoolhouse, is an outcrop of gray and yellow banded sandstone 12 to 15 feet thick. It has been quarried to some extent for local use, but the numerous irregular weather seams and the patches of iron oxide will prohibit its use in fine structures.

At the schoolhouse in the northeast corner of Sec. 35 (13 N., 6 W.) is an outcrop of sandstone somewhat similar to that on Mr. Hadden's place, but is more cross-grained and contains more iron oxide.

On the bank of Croy's creek at the section line on the north side of Sec. 35 (13 N., 6 W.) is an outcrop of argillaceous black shale containing clay ironstone concretions.

In the rock-cut on the Vandalia R. R., on the east side of Croy's creek in the N. W. quarter of Sec. 25 and the S. W. quarter of Sec. 24 (13 N., 6 W.), is an outcrop of Mansfield brownstone. The cut is eight to 15 feet deep, the rock extending to near the surface at the middle of the cut and covered with glacial drift at either end of the cut, the excavation in no place reaching the bottom of the sandstone. The stone varies in color from yellow-brown to red-brown and purplish-brown, much of it being like the Mansfield stone in color and texture, but is of no value for building purposes as it contains iron secretions, is very cross-bedded and shelly.

There is an exposure of the same bed, mostly yellow and yellow-brown in color, thin-bedded to shaly in structure, on the National road on the west side of Croy's creek in the N. W. quarter of Sec. 26 (13 N., 6 W.).

The same bed of sandstone outcrops in a more massive form north of the National road in the N. W. quarter of Sec. 26, N. E. quarter of Sec. 27 and S. W. quarter of Sec. 23. In the S. W. quarter of Sec. 23 on the east side of the ravine east of the road is a small quarry, whose face shows eight to twelve feet of light gray, yellow-stained, shelly sandstone, which contains numerous irregular seams and irregular layers varying from one inch to two feet in thickness. Down the ravine from the quarry the stone becomes more massive and, while being more difficult to quarry, is a stronger and a more durable stone. Coal has been mined in the ravine about a quarter of a mile above (northwest of) the quarry.

There is an outcrop of the Mansfield sandstone in the northwest quarter of Sec. 24 and the S. W. quarter of Sec. 13 (13 N., 6 W.) on each side of Croy's creek and each side of the wagon road. The rock lies at the base of the hill, six to eight feet being exposed. It has been quarried a little on the east side of the creek, but the heavy stripping permitted only a small quantity of stone to be removed. On the west side of the creek the slope is so gentle that there would be little stripping for twenty-five or thirty yards back from the outcrop and some good bridge stone could be obtained here.

Most of the exposures above this on Croy's creek are shale and shaly sandstone rocks of the Coal Measures. Toward the head of the creek in about the N. E. quarter of Sec. 11 is an outcrop of heavy bedded sandstone. In the N. E. quarter of Sec. 14 (13 N., 6 W.) is an outcrop of twelve to fifteen feet of blue-black shale that may prove valuable in the future.

*Mill Creek.**—Mill creek is the large tributary of Eel river from the east, in the south part of Putnam county and the north part of Owen county. It heads in the older Paleozoic rocks east of the area mapped and flows through the Lower Carboniferous sandstone and limestone, the Mansfield sandstone capping the hills on its lower course. Between the mouth of Croy's creek and that of Mill creek the Lower Carboniferous limestone outcrops in several places. On Slate Run, in Sections 15 and 16 (12 N., 5 W.) there is an outcrop of fissile black shale which is exposed in several places and contains some cannel coal. The only outcrop

*Sometimes called Eel river.

of sandstone that might have even local value is on the east side of Sec. 16 on the south side of Slate Run, where there is a ledge fifteen to twenty feet thick, the upper part of which contains stone suitable for bridges or foundations. There is an outcrop of shelly sandstone on the east side of Sec. 10, but it is too shelly and crumbling for use.

On the lower course of Mill creek the base of the hills next to the creek is of compact blue Lower Carboniferous limestone (St. Louis) which is overlain by a bed of massive, yellow, ferruginous sandstone (Mansfield), the tops of the hills being covered with glacial drift. The gentle dip of the rocks to the west causes the limestone to appear higher on the hills in ascending the creek until the Mansfield sandstone finally disappears and the glacial drift rests directly upon the limestone. Still further east beyond the limits of the map the underlying Lower Carboniferous sandstone appears.

On each side of the creek in sections 11, 12, 13, and 14 (12 N., 5 W.) the Mansfield sandstone occurs in an exceptionally heavy, massive bed. In the bluff on the east side of the creek, about 200 yards below Crouse's mill and 150 yards back from the creek, near the middle of Sec. 11 (12 N., 5 W.), the sandstone forms a bold perpendicular bluff 40 to 50 feet high. It is yellow, coarse-grained and massive, with numerous veins and patches of iron, and much of it is cross-grained. In only a few places does it weather evenly, and in no place is the stone sufficiently homogeneous in color and texture to furnish good building stone. The limestone underlying the sandstone east of Crouse's mill contains much coarsely crystalline calcite in cavities or openings in the limestone. This calcite or "tiff" has been searched diligently for "mineral." It has no commercial value outside of the few nice cabinet specimens of calcite that might be obtained.

The largest outcrop of the Mansfield sandstone on the south side of the creek is in the northwest quarter of Sec. 13 (12 N., 5 W.), at what is known as the "Buzzards' Roost." The massive sandstone here forms a semi-circular bluff 50 to 60 feet high on a small tributary of Mill creek from the south. The stone is gray, yellow and yellow-brown in color. While much of it is cross-grained and full of iron secretions, there are considerable areas where it is even-grained and comparatively free from iron and would furnish a good building stone. The good stone lies in irregular patches, and may be located on the face of the bluff by its regular, smooth surface, the cross-bedding and the iron secretions, when present, being shown by a ridged and pitted surface. The sandstone lies unconformably on a drab-colored, lumpy shale containing ironstone nodules. In places between the drab shale and the sandstone is a layer of black, very pyritiferous shale two to four inches thick. The drab shale is underlain by a compact blue limestone, which forms a waterfall in the ravine a few yards from Mill creek. The massive sandstone outcrops on the south side of Mill creek above and below the Buzzards' Roost, but none was observed that promised great economic value.

On the north side of Mill creek, opposite the Buzzard Roost, in the S. W. quarter of Sec. 12 (12 N., 5 W.), a section of the hill shows:

Section on Mill Creek, near Crouse's Mill.

	Feet.
Glacial drift	30 +
Massive yellow sandstone	40 to 50
Black shale, with coal	12
Gray and drab shale	10 +
Concealed	20
Buff sandstone	4
Limestone, compact blue	25

The sandstone contains too much iron and cross-bedding to make a good building stone.

In a ravine from the north in the S. E. quarter of Sec. 12 (12 N., 5 W.), the sandstone occurs in large quantities, in some places of a quality suitable for building stone, one of the best exposures being in a secondary ravine from the east, about one-quarter of a mile north of the creek, where it occurs in a ledge 20 to 25 feet thick, of homogeneous, durable, coarse-grained, buff sandstone, with but very little covering. The loose bowlders of sandstone in this ravine, and there are a great many very large ones, have a very hard surface. Excellent bridge and building stone could be obtained in this ravine. In some places the sandstone is underlain by a coarse conglomerate, in other places by a light gray, soft sandy shale; in still others, by a heavy bed of blue-black shale.

In section 7 (12 N., 4 W.), along the small branch known as Brush creek, the massive sandstone outcrops in considerable quantity, and none of it was observed on the north side of the creek east of this. A soft, yellow sandstone is exposed in several places, but the exposures are small and in no place has it any economic value.

At Croy's Mill in section 28 (12 N., 4 W.), in the bottom of the creek, a light gray, nearly white, sandstone occurs in the limestone. This is probably a local deposit, as it was not observed elsewhere at the same horizon, unless perhaps it might be correlated with that at Oakalla.

Along the south side of Mill creek, through 12 N., 4 W., a soft yellow sandstone outcrops in a number of places near the top of the hill and a small quantity of brownstone was observed at one place, the S. W. quarter of Sec. 28 (12 N., 4 W.). None of it observed was of any economic value, except a prominent outcrop of the Mansfield buff sandstone in section 34 (12 N., 4 W.), the west side of the section, close to the section line, and half a mile north of Mt. Pleasant church. A small watercourse has cut its way down 30 to 35 feet through a bed of massive yellow and buff sandstone, which is all or nearly all regularly bedded, mostly free from cross-grain, varying from fine-grained to coarse-grained, and extensive areas could be quarried with very little stripping. It is a promising opening for fine building stone and good bridge stone. This is the most eastern outcrop of the massive sandstone observed on Mill creek, but the overlying soft yellow sandstone outcrops at intervals for several miles east of Cataract, as far east as the middle of the south side of section 3 (11 N., 3 W.). The falls on Mill creek, or as they are widely known, Eel River Falls, one at the village of Cataract, in section 35 (12 N., 4 W.), and the other down the creek a mile northwest of the town, are both in the Lower Carboniferous (St. Louis) limestone, which forms heavy ledges of compact blue limestone. The hills on either side have a heavy covering of glacial drift, but no sandstone was observed.

Deer Creek.—The Deer Creek valley lies almost wholly in the Lower Carboniferous limestone, but on the high ground back from the creek, soft yellow micaceous sandstone and shales of the Coal Measures outcrop in a number of places as far east as the Monon Railway, and in one place, (14 N., 4 W., Secs. 28 and 33) east of the railway. This sandstone in places contains thin layers of coal, but no workable beds, nor has the sandstone any commercial value. It is thought to belong to a horizon above that of the Mansfield sandstone. The only outcrop of the typical Mansfield sandstone observed in this valley is in section 2 (12 N., 5 W.) extending west into section 3 and north into section 35 (13 N., 5 W.). In the southeast quarter of section 2, on the west side of the creek, the sandstone outcrops in a ledge 10 or 12 feet thick, massive, coarse-grained, gray and yellow colored. It outcrops along the bluff west into the southeast quarter of section 3, but in no place has any economic value. North from the ford of the creek the sandstone outcrops along the west side of the creek into section 35 (13 N., 5 W.), the best exposure being in the northeast quarter of section 2 (12 N., 5 W.), where the stone has a light gray, nearly white color. The loose boulders, of which there are a great many, have a very hard surface, but the stone appears to be no harder than the average, an inch or more beneath the surface. Good stone for local use in bridges, foundations, or even superstructures, could be obtained at this place.

On the ridge between Deer creek and the Duweese branch, on each side of the National road between Manhattan and Putnamville, sandstone, shale, and coal outcrop in several places. A sandstone quarry was opened, but not worked to any extent, north of the National road about a mile east of Manhattan in section 13 (13 N., 5 W.). The sandstone is for the most part soft and shelly. Coal has been mined north of the road in section 18 (13 N., 4 W.).

On the hill south of Forest Hill Cemetery, at Greencastle, in sections 28 and 33 (14 N., 4 W.), shaly sandstone, shales, and fire-clay with traces of coal are exposed, but have no economic value.

Soft yellow sandstone outcrops on the hills west of the Monon Railway between Putnamville and Cloverdale, but there is none of value.

Limestone has been quarried in several places in the Deer Creek valley. It has been quarried for local use from the bluff underlying the sandstone bed just described above in section 2 (12 N., 5 W.). There are much larger quarries in sections 8 and 17, on the north side of the National road near Putnamville, where an excellent flagstone and good building stone has been quarried for many years. There are other quarries at Greencastle Junction, southwest of Greencastle, and at the town of Greencastle.*

Big Walnut Creek.—There is comparatively little of the Mansfield sandstone along the main Big Walnut creek, and what there is has but little commercial value. Sandstone in large quantities occurs on Snake creek and Little Walnut creek tributaries, and will be described under these headings.

Soft, shaly sandstone and shales of the Coal Measures outcrop in various places on the hills bordering Big Walnut creek between its confluence with Mill creek and its confluence with Little Walnut, in the west part of 13 N., 5 W., and the north part of 12 N., 5 W., but none of any economic value.

Mansfield sandstone of inferior quality outcrops on the west bank of Walnut creek on the east side of section 4 (12 N, 5 W.,) west of the wooden bridge. About one mile above the bridge in the southeast quarter of section 33 (13 N., 5 W.,) is a small outcrop of compact blue limestone in the creek bed, overlain unconformably by a sandstone-shale conglomerate and a very pyritiferous sandstone.

There is a heavier ledge of the sandstone (twelve to fifteen feet) in the northeast quarter of section 32 (13 N., 5 W.,) west of the wagon road and more than a quarter of a mile west of the creek. It is underlain by fire-clay and shale. The sandstone contains too much iron ore and false bedding to have any economic value. In the north part of section 32 and the south part of section 29 sandstone outcrops in a number of places, but contains much iron ore and is soft and shelly.

On Johnson's branch in the south part of Sec. 7 (13 N., 5 W.), on the small tributary from the east and above and below it is an outcrop of yellow sandstone and black shale. Small quantities of sandstone suitable for foundations could be obtained here but there is too much overlying drift material to permit the quarrying of large quantities. In the

*The limestone quarries will probably be described in detail in future volumes of the survey reports.

northeast quarter of Sec. 7 (13 N., 5 W), the false-bedded yellow sandstone in the bottom of the valley next to the watercourse is overlain by a heavy bed of shale 25 to 30 feet thick. Small quantities of thin-bedded sandstone have been quarried for local use from a small outcrop near the head of Johnson's branch, west and southwest of the middle of Sec. 6 (13 N., 5 W.).

A section of the bluff on the south side of Big Walnut creek at Reelsville shows:

Section at Reelsville.

	Feet.
Glacial drift	8
Shelly, coarse-grained, yellow sandstone (Mansfield)	14
Drab sandy shale	8
Hard semi-crystalline, reddish, encrinital limestone	3
Drab sandy shale	12
Shelly limestone and sandy shale	2
Black and gray sandy shale	2
Compact, blue-gray, fossil limestone	10
Black shale (slate)	10
Compact blue limestone	20

The upper sandstone in this section belongs to the Carboniferous, while all the underlying are Lower Carboniferous. The sandstone has no value.

About three-fourths of a mile east of Pleasant Garden, on the south side of the National road, is an outcrop of the Mansfield sandstone in which a quarry was opened, but soon abandoned. The stone is exposed in the bluff 10 or 12 feet thick with but little overlying material and underlain by compact blue limestone. It is quite variegated in color, at the east end of the bluff the gray body containing many yellow and yellow-brown spots and stripes, while towards the west end of the bluff the spots are red and red-brown. There are many irregular seams, some of which may be due to the powder used in blasting it, but most of which are probably due to the action of the weather. The stone might be used for small bridges and foundations but is unfit for superstructures. A somewhat similar stone outcrops on the creek bluff south of the Vandalia Railroad in the northeast quarter of Sec. 22 (13 N., 5 W.), where the exposure is larger but with no improvement in the quality.

The town of Reelsville is located for the most part on the rocks of the Coal Measures. The Lower Carboniferous limestone outcrops at the base of the hill, 25 to 30 feet above the creek. The Vandalia Railroad west of the depot has cut into this limestone several feet. Overlying the limestone is an outcrop of soft sandstone and shale, the shale predominating, and in one place the shale is richly impregnated with iron ore. It is possible that a shale suitable for making paving brick could be obtained here.

A soft, yellow sandstone with intercalary shale outcrops in several places along the branch from the northwest just above Reelsville in sections 16, 8, and 9 (13 N., 5 W.), but so far as observed it has no economic value. The Lower Carboniferous limestone, overlain by a green shale, outcrops along the branch and base of the hill for more than a mile from its mouth.

Between Reelsville and Snake creek, along the west side of Big Walnut, the Mansfield sandstone outcrops in a number of places through sections 22, 15, 10, and 3 (13 N., 5 W.), but it contains iron secretions and much false bedding, which renders it unsuitable for building purposes, unless it be for foundations. It occurs in a massive bed ten to twenty feet thick along the creek bluff, in some places underlain by black shale containing thin layers of coal.

Along the east side of Big Walnut creek, opposite the bluff described above, is a wide bottom bordered by gentle slopes, on which are a few exposures of Lower Carboniferous limestone. The only sandstone on the east side is a thin bed of shaly sandstone and shale on the hill northeast of Hamrick station, more than a mile east of the creek, but it is too shelly to have any value. There are extensive limestone quarries at Oakalla, in the south part of Sec. 26 (14 N., 5 W.) and at Greencastle, which have been in operation for many years. In one of the quarries at Oakalla the compact blue limestone is overlain conformably by three to four feet of thin bedded light gray, nearly white, calcareous sandstone, which appears to be a local occurrence, as it was not found elsewhere in the vicinity. It may correspond stratigraphically with that occurring at Croy's mill, mentioned elsewhere.

Snake Creek, tributary of Big Walnut Creek.—Snake creek, a small tributary of Walnut creek from the west in the south part of 14 N., 5 W., cuts through considerable sandstone, the Mansfield stone being along the lower course and the overlying Coal Measures about the head waters. The sandstone lies unconformably on the limestone, as shown by the large limestone outcrop at and north and east of Fern station, and another outcrop in the east side of Sec. 32 (14 N., 5 W.), while along the south side of the creek the sandstone outcrops in large quantities, in some places down at least to the creek bed and below it.

The largest outcrop of sandstone on Snake creek is at the Fern picnic grounds on the east side of section 33 (14 N., 5 W.), where the best stone for building purposes is in the southeast quarter, section 33 (14 N., 5 W.), in a ravine from the south, about a quarter of a mile below (southeast of) the picnic ground. The sandstone outcrops in a bold bluff 60 feet high (Bar.). The color varies from light gray to yellow. It has a coarse, even grain and weathers evenly, the surface being marred only by a few weather seams. There is at this point a fine bed of building stone, adapted to bridges, foundations or superstructures. As some of the stone is variegated in color, building stone could be profitably quarried only by having a market for the variegated stone, which is suitable for bridge work or foundations. The stone is quite soft and easily worked, but hardens on exposure. It has not been quarried, not even for local use, as it is thought to be too soft. The occurrence of these bold bluffs is proof of its durability, and the examination of the exposed surface shows that it hardens sufficiently for practical purposes. Where the color of this stone is suitable for the work in hand it can be used with perfect safety so far as strength and durability are concerned, providing the stone is quarried without heavy blasting and not too late in the season, so that it can dry out before the freezing weather.

The bluffs at the picnic ground are higher than the one described above, in one place measuring 85 feet, but the stone is more variegated in color, contains some iron secretions, and is cross-grained in places. With care in selecting, good bridge stone could be obtained from these bluffs, and a closer examination might show some sufficiently uniform in color for good dimension stone.

There is an extensive outcrop of yellow Mansfield sandstone on a small tributary of Snake creek from the south, south of Fern Station, east and southeast of the picnic grounds. A small branch of this tributary, which heads at Mr. Roger's house, in the northwest quarter of section 4 (13 N., 5 W.), and flows east through his farm, has an almost continuous bluff of yellow sandstone 10 to 25 feet high along the south side. In most places the sandstone extends to the bottom of the valley, but in a few places there is an outcrop of blue-gray and black shale underneath the sandstone. The stone resembles that described at Fern Cliffs in being yellow colored and quite soft when green, but hardening on exposure. It lies in good position for quarrying, forming low bluffs along the watercourse, and having very little covering, in some places none. Near the middle of the west half of section 4 (13 N., 5 W.) two wells dug 50 to 75 yards back from the face of the bluff went through 8 feet of drift material and penetrated 30 feet into the sandstone. In a few places the rock shows cross bedding, but most of it is evenly bedded, fairly homogeneous in color and texture, and would furnish good building stone. No stone outcrops on the north side of this branch, the slopes there being covered with glacial drift.

Up Snake creek, about two hundred yards west of the cliffs, is an outcrop of three to four feet of black fissile shale or slate which is highly carbonaceous and contains much pyrite. It splits easily into sheets two or three feet across, but it is too pyritiferous to stand exposure to the weather. It is underlain by a crumbling, lumpy shale and overlain by shelly sandstone.

Sandstone is exposed at intervals to the head of Snake creek and on most of the small tributaries from the north. It outcrops in a massive ledge on Mr. John's place on the south side of Sec. 21 (14 N., 5 W.), where it is underlain by fire-clay and shale, and on Mr. Goodman's place in the S. E. quarter of Sec. 29 (14 N., 5 W.), and in several other places along the ridge north of Snake creek. The only stone of any economic value west of the cliffs is that in a small ravine from the north, just north of the I. & St. L. Railway, in the northeast quarter Sec. 31 (14 N., 5 W.), where the stone is evenly bedded, light gray to buff in color, and is exposed 12 to 15 feet, the bottom being concealed. Some stone has been quarried here for use on the railroad and much more could be obtained. The sandstone exposed along Snake creek through Sec. 32 (14 N., 5 W.) contains much iron pyrites, false bedding and patches of shale, so that it has no economic value.

Little Walnut Creek.—Little Walnut creek has cut a channel in the Lower Carboniferous limestone close to the eastern border of the sandstone of the Coal Measures. The Lower Carboniferous limestone is exposed along the bottom of the valley and base of the bluffs; the sandstones and shales of the Coal Measures form the upper part of the hills, occurring in large quantities on the west side of the basin and in small quantities on the east side.

The largest exposures of sandstone in the Little Walnut Creek basin are those along Long Branch in the west and northwest part of 14 N., 5 W. On the hill west of the mouth of Long Branch, in Sec. 27 (14 N., 5 W.), the northeast quarter, and Sec. 22, the southeast quarter, on Mr. Stoner's place, the sandstone outcrops in a massive ledge 60 to 75 feet thick, 90 to 100 feet above the creek. The following is a section of the hill at Mr. Stoner's:

Section at Mr. Stoner's, on Little Walnut Creek.

	Feet.
Glacial drift	30+
Massive sandstone (Mansfield)	70
Black and blue shale	15
Compact blue limestone (Lower Carboniferous)	65+
Total	180

There are two abrupt overhanging cliffs of the sandstone 50 to 60 feet high, one in Sec. 27 and one in Sec. 22, each being horseshoe shaped and in a small ravine. Between the cliffs the stone outcrops in a few places but the slope is mostly covered with gravel. In the bluff in Sec. 27, the more southerly one, there is more stone exposed, the bluff being 10 or 12 feet higher, but the quality of the stone is inferior to that in the other bluff, having numerous iron secretions and weathering unevenly. In the more northerly cliff the stone is comparatively free from iron, except about eight or ten feet at the base which is pyritiferous. It is fine-grained, homogeneous in texture and presents a smooth, clean surface on the weathered exposure. The stone is buff to cream-colored in the upper part of the bluff, grading to a light gray near the base, the light gray having faint patches of dull yellow, that would possibly become more numerous on exposure. It is difficult to estimate the proportion of light gray, but at the face of the cliff it probably forms not less than one-fourth of the whole. It is quite probable that back from the face of the cliff in the interior of the bed the greater part of the stone is of a light gray color, the buff color being due largely to greater oxidation of the iron in the stone. It contains a considerable per cent. of the amorphous-looking chert grains.

As there is probably a thickness of 35 or 40 feet of excellent light gray and buff sandstone at this point with very little loose material on top of it, an almost inexhaustible amount of good building material could be quarried at a moderate expense. The stone in the interior is soft, by many it will be thought too soft for building stone, but it should be noticed that the exposed portions of the upper part of the bluff and the loose bowlders on the hillside south of the bluff are extremely hard. It is the shaded portion under the overhanging bluff that is soft. The softness is not due wholly to its being shaded but to the fact of its being saturated with water.

Sandstone of inferior quality outcrops in a number of places west of Mr. Stoner's farm on the hill south of Long Branch. On the north side of the branch the hills are mostly covered with drift, very little rock being exposed. North of Brunerstown in the northwest quarter of Sec. 17, the southwest quarter of Sec. 8 and the east side of Sec. 7 (14 N , 5 W.), the sandstone outcrops on both sides of Long Branch, forming bold cliffs close to the creek, and extending beneath the bottom of the valley, the Lower Carboniferous limestone being below the drainage level. Much of the stone along this part of the branch contains too much segregated iron for good building stone. Good bridge and foundation stone could be obtained in a number of places by careful selection. The best stone observed in this region is a little more than a quarter of a mile southeast of Mr. Wiley's house in the northeast quarter of Sec. 7 (14 N., 5 W.), where the bluff is 30 to 40 feet high, composed of buff and light gray sandstone containing a few small specks of iron pyrites, and mica flakes and numerous chert grains. The sandstone is exposed in several places north, northeast and northwest of Brunerstown, but none of any value was observed. Along the small tributary of Long Branch from the west in the northeast quarter of Sec. 18 (14 N., 5 W.) the sandstone exposed is 20 to 25 feet thick and darker in color than at any other place along Long Branch.

On Leatherman branch in sections 4 and 5 (14 N., 5 W.) a heavy sandstone ledge occurs somewhat similar to that described on Long Branch. In the northeast quarter of Sec. 5 it is exposed 15 to 35 feet, and is of a dark yellow to yellow-brown color. It is remarkably free from iron or conglomerate, the weathered face showing lines of weakness parallel with the bedding, due probably to shaly or argillaceous material. For more than a half mile southeast from this point the branch cuts its way through this bed of sandstone, which forms bold cliffs on either side.

On the other or north prong of Leatherman's branch is an outcrop of sandstone similar to that described above. In several places along this prong the Lower Carboniferous limestone is exposed. The best sandstone observed is that near the upper limit of the outcrop in the northwest quarter of Sec. 4 (14 N., 5 W.) near the township line. The bluff is 40 to 50 feet high, 10 to 12 feet at the base being concealed. The stone is mostly buff-colored, but variegated gray and brown at the base. Small streaks of iron conglomerate occur in places. Good stone for local use could be obtained here.

In Sec. 10 (14 N., 5 W.), just west of the confluence of Leatherman and Little Walnut creek, is a ledge of massive Mansfield sandstone 10 to 15 feet thick, underlain by compact blue limestone exposed 15 to 20 feet above the creek. In the northwest quarter of Sec. 10 on a small tributary of Leatherman's branch from the west is an outcrop of fine-grained gray-colored sandstone which has had considerable local use for whetstones and grindstones.

On Mr. Wright's place on the east side of Little Walnut creek, in the southeast quarter of Sec. 11 (14 N., 5 W.) is an outcrop of bituminous coal which varies from thirteen to twenty-six inches in thickness and which has been mined for local use. The coal is underlain by fire-clay and in turn by massive yellow sandstone which outcrops in massive ledges in the ravine below the road and in other ravines east and west of the coal. Less than a quarter of a mile south of the coal mine a small chalybeate spring emerges from the base of the massive sandstone which here contains thin patches of shale. In the valley south of the spring, in sections 13 and 14 (14 N., 5 W.) the Lower Carboniferous limestone which outcrops in large quantities contains much nodular chert, and both the chert and limestone contain fossils.

Sandstone outcrops further north in the Little Walnut Creek valley at the following places: Sec. 2 (14 N., 5 W.) the S. E. quarter; in Sec. 35 (15 N., 5 W.) the N. W. quarter; and Sec. 34 the N. E. quarter; Sec. 27 the N. W. quarter; Sec 22 the S. W. quarter; Sec. 28 the N. W. quarter; and Sec. 20 the S E. quarter and N. E. quarter. The largest outcrops are in the southeast quarter of Sec. 20 and the northwest quarter of Sec. 28, where the stone occurs in a massive bed twenty-five feet thick, but as in the other exposures mentioned, it is too variegated in color and contains too much iron pyrites for building stone.

The Lower Carboniferous limestone outcrops in many places in the vicinity of the above sandstone exposures. It has been quarried at Clinton *Falls in the* north part of Sec. 28 (15 N., 5 W.) at Mr. Holland's, in the south part of Sec. 22 (15 N., 5 W.) and in the southwest quarter of Sec. 13 (15 N., 5 W.) Good building stone occurs at the last two places, and stone good for burning into lime may be obtained at almost any of the numerous exposures in this valley.

Big Walnut Creek above its confluence with Little Walnut Creek.—In the northeast part of Putnam county, east of Bainbridge and Carpentersville, sandstone similar to that at Riverside, Fountain county, has been quarried in several places. It appears to correspond in position to the formation called the Knobstone in the former State reports, but is referred to elsewhere in this paper as the Riverside sandstone.

It is a fine-grained homogeneous sandstone, blue on the interior of the bed, but drab to buff on weathered exposures. In places it contains considerable pyrite which forms a white efflorescence on the weathered surface. At a depth not affected by the weather, the stone is probably massive in most places; that it is in some places is shown by its occurring so in the abrupt cliffs along the creeks where it has not been so long exposed to the elements. On the weathered exposures, incipient bedding planes develop at more or less frequent intervals, which are in general horizontal and parallel with each other, thus greatly facilitating the quarrying of the stone where they are not numerous enough to injure it. The contact between the interior blue color and the exterior buff is shown in some places by a sharp line.

It has been quarried to considerable extent in two places and in smaller quantities at other points along Big Walnut creek in the northern part of Putnam county (not shown on the accompanying map sheet). One of the quarries, now owned by Mr. Miller, is in the south part of Sec. 29, (16 N., 3 W.), on the east side of the creek, on the south side of the wagon road from Carpentersville to New Maysville. The rock outcrops on a bold cliff on the bank of the creek, a section showing:

Section on Big Walnut Creek east of Carpentersville.

	Feet.
Soil	2
Sandy shale	10
Sandstone, face of quarry	25
Sandstone to bottom of creek	35
Total	72

The upper part of the quarry face shows thin-bedded stone (2 to 6 inches) merging into the overlying shale. The lower part of the quarry is in layers six inches to three feet thick. The bluff beneath the quarry is heavy bedded, two to four feet, and contains scattered pyrite nodules. The stone has had a local use for many years; possibly 5,000 cu. ft. in all have been quarried. Its principal use has been for bridge abutments and foundations, the abutments of the bridge across Walnut creek at this point being built of this stone. The bridge is said to have been constructed 15 years ago, and the stone shows no evidence of decay at the present time.

The other quarry referred to is Mr. W. H. Rice's on the west side of Sec. 8 (15 N., 3 W.), on the east side of the creek, on the north side of the Bainbridge–New Maysville wagon road. A detailed section of the quarry face shows:

Section at Mr. Rice's Quarry.

Shaly sandstone and shale	8 feet.	
One layer buff sandstone	1 foot.	
One layer buff sandstone		10 in.
One layer buff sandstone		9 in.
One layer buff sandstone		8 in.
One layer blue sandstone	2 feet.	
One layer blue sandstone		10 in.
One layer blue sandstone	2 feet	6 in.
One layer blue sandstone	3 feet.	
One layer blue sandstone	3 feet.	
Total	22 feet	7 in.

The stone resembles that at the Miller quarry described above. The bedding planes will probably be less numerous in the interior, the beds becoming thicker but retaining an easy horizontal cleavage. None of the pyrite nodules were observed here, but there is much finely diffused pyrite, and in places small leaf-shaped soft patches which would injure the stone for fine work where they occur. There is not as much stone available at this point as at the Miller quarry, since the slope above the quarry is much steeper and the stripping would soon become too expensive. However, the supply would probably never be exhausted by the local demand. The quarry is said to have been opened two years ago and the stone used mostly in bridge abutments.

There are doubtless many exposures of this stone along Walnut creek that might be quarried to advantage, but no others were examined.

Raccoon Creek Basin.

The Raccoon Creek valley, which lies near the middle of the Brazil Sheet, contains a great quantity and many varieties of sandstone. The headwaters of both Big Raccoon and Little Raccoon creeks lie in the Lower Carboniferous limestones and sandstones east of the limits of the accompanying map, and both creeks cut a channel of considerable length through the Mansfield sandstone and then into the overlying Coal Measures, through which both flow for some miles above their confluence, as well as the main stream from the confluence to the Wabash river. Both creeks have a general southwesterly course to near their confluence, where the main stream takes a sudden turn to the northwest.*

Sandstone in the greatest quantity and of the best quality occurs along that part of its course where it cuts through the Mansfield sandstone at the base of the Coal Measures. However, good building stone occurs in the lower course, in the overlying sandstone of the Coal Measures, and stone less valuable in the Lower Carboniferous rocks. Sandstone has been quarried in each of these formations in the Coal Measures at Coxville and on Stranger's Branch (14 N., 7 W.), in the Mansfield stone at Mansfield, Judson, Portland Mills and intervening points; in the Lower Carboniferous (Riverside) at Raccoon station.

Both the brownstone and the gray and buff varieties occur on both Little Raccoon and Big Raccoon creeks and on Rocky Fork, southeast of Mansfield. The most valuable stone occurs near Fallen Rock, on Little Rocky Fork, near Mansfield and Portland Mills, on Big Raccoon creek, and near Judson, on Little Raccoon creek.

The lowest exposure examined in the Raccoon Creek valley is that on the east side of the creek at Coxville, on the C. & I. C. Ry., in section 15 (14 N., 8 W.). Stone is said to occur at Mecca and other points north of Coxville, but was not examined.

The quarry at Coxville, known as the Evans quarry, has been operated more or less spasmodically for a number of years by William Evans. No figures in regard to the production could be obtained.

The stone is a coarse-grained buff sandstone, slightly variegated in places, occurring in a massive irregular deposit, having a maximum thickness of outcrop of about fifty feet. However, at few points is there a thickness of fifty feet of massive sandstone, in most places a considerable thickness of shelly sandstone, black shale and coal occurring with the sandstone. Coal has been mined near the base of the bluff at each side of the quarry.

A fair quality of bridge and building stone could be obtained here in large quantities. It would be necessary to handle considerable inferior rock to get it, and it is doubtful if the quarry could be operated profitably on a large scale unless some use could be made of the rough stone.

In the former State reports this rock is classed as conglomerate (corresponding to the Mansfield stone), but no evidence is given in support of the statement. The hasty field examination does not support such a view, yet the evidence was not sufficient to state positively that such might not be the case. It seems more probable that it is of more recent age and belongs in the Productive Coal Measures. If it were Mansfield stone the Coal Measures should rest unconformably upon or against it, which does not appear to be the case, as the sandstone spreads out over

* It is possible that at one time in its history this stream had a direct course southwest to the Wabash river instead of the big northwest bend it now has.

the coal on either side. This coal might be the so-called sub-conglomerate coal, but there is no positive evidence that such is the case.

There is a small outcrop of sandstone on the south side of the creek at and below the gristmill at Bridgeton, section 22 (14 N., 7 W.). It is variegated yellow and yellow-brown in color, very shelly and accompanied by considerable shale. It has no economic value and is apparently of the age of the Productive Coal Measures.

On Mr. Mitchell's farm, on the north side of the creek, a quarter of a mile north of the bridge at Bridgeton, is a sandstone quarry from which stone for local use has been obtained. It is a micaceous yellow and gray variegated shaly sandstone, twelve to fifteen feet thick; a few layers, two feet or more in thickness, might furnish a fair quality of stone, but most of it is too thin-bedded and shaly to have much value.

Sandstone is exposed in a number of places along Stranger's Branch northeast of Bridgeton in sections 1, 2, and 11 (14 N., 7 W.) and section 36 (15 N., 7 W.), but all of inferior quality for building stone; much of it is suitable for well curbing, foundations, or small bridges.

Mansfield.—Although not in operation at the present time, the quarry at Mansfield, 14 N., 6 W., section 5, has produced more brownstone than any other one quarry in the State. The quarry is situated on the north side of Raccoon creek a quarter of a mile north of east from the village of Mansfield on the south side of section 5 (14 N., 6 W.), on property formerly belonging to Mr. Smith.*

The quarry was first worked by M. W. Wolf, of Chicago, in 1887. Mr. Wolf operated the quarry until 1891, four years, when he sold out to the Parke County Brownstone Company, who continued the business until 1894, when it passed into a receiver's hands and work in the quarry ceased.

The company employed about forty men, about twenty being in the quarry, had two steam channeling machines, two steam-power and one horse-power derricks, and a steam saw gang. A branch railroad was built to Brazil, and stone was shipped to Evansville, Terre Haute, Fort Wayne and Indianapolis, Ind.; Owensburg, Ky.; Paynesville, O.; Chicago and Roseville, Ill.; Wymar, Neb., and for bridge stone on the C. & E. I. R. R.

The dressed stone was sold at 65c. to $1.25 per cubic foot and the rough stone at $2.50 to $4 per cubic yard. During the busy season the company shipped at the rate of one car-load per day.

Plate XIII shows the Mansfield brownstone quarry about the time it was first opened and plate XIV a view of it shortly before it closed. It may be noticed that the numerous weather seams of the surface in the first view have disappeared in the interior of the bed in the second view,

*The information in regard to the owner's shipments, etc., of the stone was obtained from Mr. Smith.

MANSFIELD BROWNSTONE QUARRY, MANSFIELD, INDIANA, WHEN FIRST OPENED.

where the stone is massive. The weather-seamed surface of the outcrop, while denoting lack of perfect homogeneity in the rock, does not signify lack of durability as much as it might under other conditions. It is noticeable that in many places throughout the State, where the hillsides facing north have a bold outcrop of rock, the one facing south on the opposite side of the valley has either no rock exposed, being covered deeply with soil, or else a very much weathered, crumbling exposure. This quarry is on the south slope.

The total thickness of the stone exposed at the quarry is thirty to thirty-five feet, but the bottom is not exposed and the total thickness is not shown. About 200 yards east of the quarry opening, an opening made with a core drill showed thirty-three feet* of brownstone, underlain by fifty feet of lighter yellow colored sandstone. Not all of the stone exposed on the present quarry face is good building stone; in fact there is more worthless stone exposed than there is good stone.

The most injurious constituent of the rock is the large number of iron "kidneys" or "blisters" scattered through it. These are hollow shells and lumps of iron oxide, varying from a half inch to two or three inches in diameter, which are quite abundant in certain parts of the bed. These blisters are due in many cases to the pebbles originally in the rock, which have been changed to iron oxide by replacement by the infiltrating waters. They are not simply a surface phenomenon, but are just as liable to occur far in the interior of the bed. The patches of shale and shaly sandstone injure much of the stone, necessitating the handling of so much waste material These are most abundant at the west end of the quarry, disappearing entirely on the bluff east. The iron blisters continue along the face of the bluff for 150 to 200 feet east of the quarry and less frequently further east. From the large amount of waste material to be handled it is doubtful if any more stone could be raised with profit from the present quarry opening. A more promising opening, so far as can be determined from the surface, is on the bluff some 200 yards north of east of the present opening, near where the core was taken out by the diamond drill. The stone at this point is not wholly free from the iron oxide, but more nearly so than at points further west. The top of the bluff at this point has been planed off by the glacier (striæ S. 45° E.), being ten to twelve feet lower than it is seventy-five yards further east. Eastward the stone changes into a yellow and yellow-gray color, with segregated veins and patches of the iron oxide. At the middle and west end of the quarry there is a layer of chert conglomerate ("peanut rock") overlying the sandstone. It is made up of subangular pieces of chert from the underlying limestone, imbedded in the sand and iron oxide, and attains a thickness of four or five feet in places.

* According to the statement made by Mr. Smith.

Several different shades of brownstone occur at this quarry, but the mass of the stone is a rather dark purplish red-brown, which gives a brighter red-brown powder when crushed. The color is due to the abundance of hematite in the stone. It contains numerous small light gray specks uniformly distributed, which can only be seen on close inspection and have no other effect than to give the body of the stone a lighter shade than it would otherwise have.

There are other shades due to the mixture of the more hydrous oxides of iron; these occur in comparatively small quantities and it is only by quarrying the stone in large quantities and selecting the colors that they can be used to advantage for building stone.

In places the stone is strikingly banded gray and dark brown, the bands about half an inch to an inch in width and inclined about 30° to the horizontal. These bands mark the lines of cross-bedding along which the iron-bearing waters have penetrated, depositing more iron in some bands than in others.

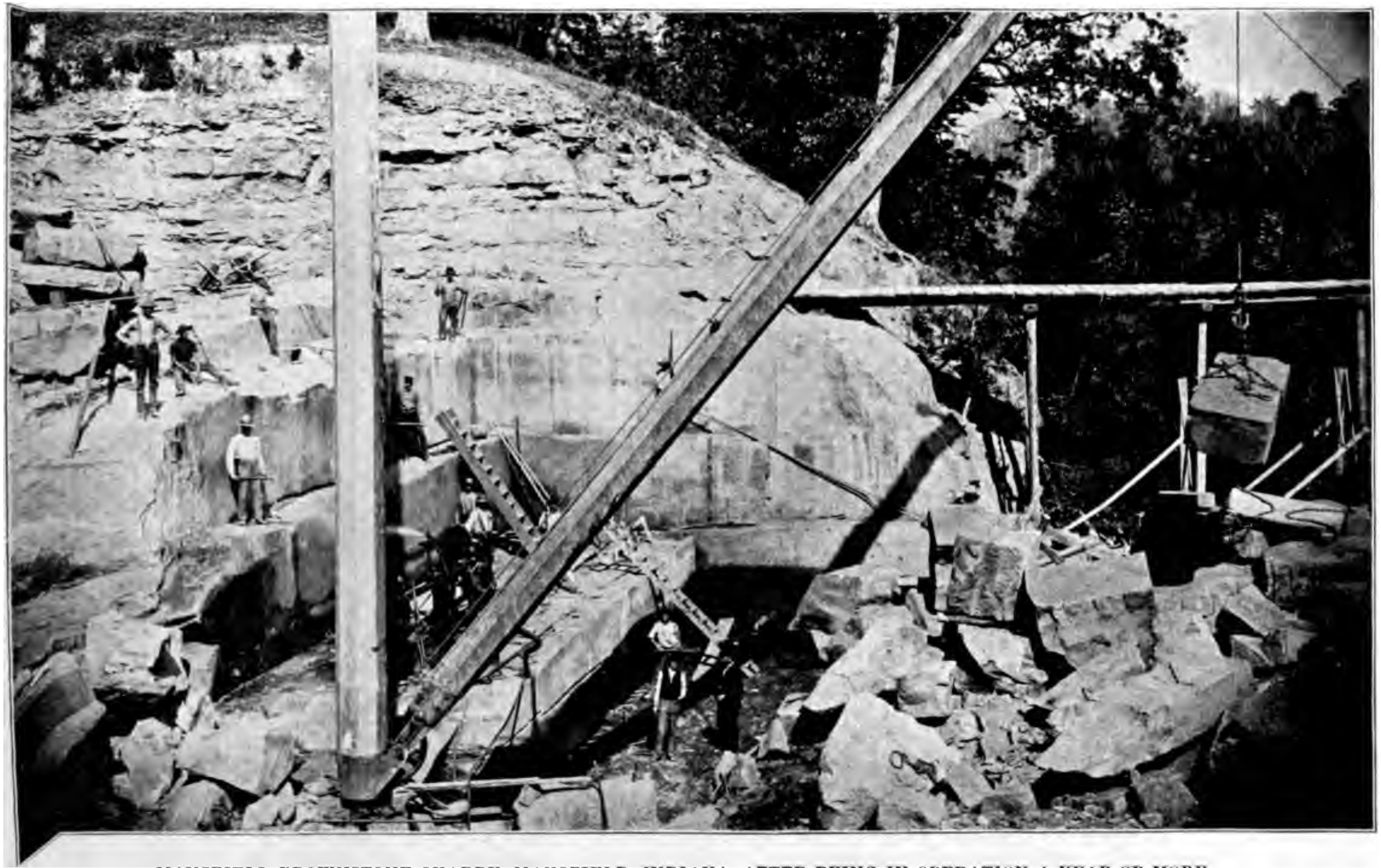
For chemical analysis, microscopic character, etc., of the Mansfield sandstone see Chapter III and plates XI and XII.

In the narrow ridge above, (southeast of) the quarry in the southeast quarter of Sec. 5 (14 N., 6 W.) buff sandstone outcrops in a number of places, but it contains too much iron and has too heavy a covering of loose material to be of value; no brownstone was observed. On the north side of this ridge on the north side of Sec. 5 (14 N., 6 W.) the buff and gray sandstone forms a precipitous bluff in several places, but is highly ferruginous in all the outcrops.

In the bluff on the south side of Raccoon creek, east of Mansfield, in the northwest quarter of Sec. 8 (14 N., 6 W.) massive sandstone is exposed and has been quarried at intervals for a distance of 200 yards along the bluff. At the south end of the bluff the stone has a red-brown color much like that in the quarry north of the creek, but there are patches of a brighter red color than any of that on the north side of the creek. At the north end of the bluff the stone is light gray to buff, and is overlain by a thin layer of the chert conglomerate similar to that across the creek, but there are very few pebbles or iron blisters in the body of the rock. In fact the stone is more uniform and freer from impurities in this bluff than in the larger quarry north of the creek, but it is unfortunately overlain by a heavy bed of drift material twenty-five to thirty feet thick.

The stone quarried from this bluff has been for local use. The stone in the bridge across Raccoon creek, at Mansfield, is said to have been taken from this place. This bridge was built in 1868–9, and the stone work is yet sound, except the bottom course in the middle pier, which is much decayed.

PLATE XIV.



MANSFIELD BROWNSTONE QUARRY, MANSFIELD, INDIANA, AFTER BEING IN OPERATION A YEAR OR MORE.

W. H. Pruitt's Quarry.—On W. H. Pruitt's farm on the east side of Raccoon creek, in the N. E. quarter of Sec. 5 (14 N., 6 W.), and the N. W. quarter of Sec. 4, is a rounded hill with buff, gray and brown sandstone outcropping on the southwest and north sides. A small quantity of the stone has been quarried on the northwest side of the hill. The quarry has been opened in the brownstone, which, like that at Mansfield, consists of different shades. The prevailing color is a purplish brown with a steel gray lustre, but the general color of the stone is lighter than the Mansfield stone. There is a thickness of about ten feet of the brownstone exposed at the quarry, underlain by buff sandstone and overlain by drift material, which slopes up rapidly to a height of 25 feet or more above the sandstone exposure. How thick the brownstone may be under this drift can not be determined from the surface. No iron secretions, which proved such a serious drawback to the Mansfield stone, were observed at this place; there is a little cross-bedding. The color and texture of the stone are good, and some good stone has been taken out. Whether it can be profitably obtained in quantity depends upon the character and thickness of the brownstone under the drift and the amount of stripping that will be necessary. This could be determined by drilling a few holes on the hill above the quarry opening. The brownstone outcrops also on the south side of the hill, while on the immediate creek bluff on the west end only buff sandstone was observed.

Rocky Fork Branch of Raccoon Creek.—Rocky Fork, with its tributaries, drains nearly all of Jackson township, Parke county (14 N., 6 W.), the head branches extending into the townships north and east. It has cut a network of channels through the massive Mansfield sandstone, exposing that rock in many places. The most valuable stone in the valley is that exposed on Little Rocky Fork in the vicinity of "Fallen Rock" and on "Straight Branch" of Big Rocky in the north part of Sec. 10.

Sandstone is exposed on each side of the creek between the confluence of Big and Little Rocky Forks and that of the main stream with Raccoon creek, the largest exposures being on the west side of the creek. On the east side of the wagon road on the west side of the creek, in the northeast quarter of Sec. 8 and the northwest quarter of Sec. 9 (14 N., 6 W.), the thickness of the sandstone exposure is about 25 feet, of which the upper 12 to 15 feet have a red-brown color like the Mansfield stone. It contains much cross-bedding and many iron blisters. The bottom of the exposure is light colored and contains patches of shale. There is none of it suitable for building stone.

There is an outcrop of similar stone in the southwest quarter of section 9 (14 N., 6 W.), and at intervals between it and the above, but it has no economic value. The same is true of all the stone observed in sections 16 and 15 (14 N., 6 W.). The largest exposures are on a small tributary from the southeast in the northeast quarter of section 15 (14 N., 6 W.), where the stone is 35 to 40 feet thick, forming perpendicular to overhanging bluffs. Most of it contains iron secretions, but there are a few small patches comparatively free from iron, from which good bridge stone might be obtained in limited quantity.

On the lower part of *Straight* Branch, in the south part of section 10 (14 N., 6 W.), the stone is ferruginous, cross-bedded, yellow and buff colored, but in the north part of section 10, above the chalybeate spring, the character of the rock is much improved.

About 50 yards north of the spring, on the west side of the branch and 20 feet above it, a sandstone ledge three to four feet thick is exposed. It is free from iron secretions and cross-bedding, has a good texture but lacks homogeneity of color, varies from gray and buff to light brown and bright red. About 100 yards above the spring is a small outcrop of lumpy limestone in the bottom of the valley.

North of the limestone, beginning at about 200 yards north of the spring and continuing almost all the way for a quarter of a mile or more along both sides of the branch, are sandstone bluffs 30 to 40 feet high, containing even-grained, evenly bedded sandstone, heavy bedded and uniform in texture. It varies in color, but is uniform through considerable thicknesses. Buff and yellow are the prevailing colors, but there are patches of considerable size of bright brick-red color. It is doubtful if the red could be obtained in large quantities, but excellent buff and yellow stone could be obtained in unlimited quantities.

The water from the chalybeate spring, near the middle of section 10 (14 N., 6 W.), is strongly charged with iron, and has formed a considerable deposit of bog iron ore around it. It is a strong flowing stream.

On the tributary of Rocky Fork, known as *Ground Hog Branch*, in sections 11 and 12 (14 N., 6 W.), the Mansfield sandstone outcrops in several places, but contains too many iron segregations and too much cross-grain to have any commercial value. On the west side of section 12 is a bed of black shale 25 feet thick overlying the massive sandstone. It contains thin seams of coal and sandstone.

Along Big Rocky Fork, above its confluence with Ground Hog Branch, in sections 2 and 11 (14 N., 6 W.), are many high rugged cliffs of sandstone, in some places 60 feet or more in height. In most places it is very false-bedded and contains intercalary patches of black shale. In a few places small areas of the sandstone occur, free from false-bedding and comparatively uniform in texture and color. Such an area which promises considerable good stone is near the middle of the north half of section 11 (14 N., 6 W.), where the evenly bedded buff-colored sandstone at the top of the cliff, varying from 30 to 50 feet in thickness, is underlain by black shale and false-bedded sandstone. Good stone for local use could be obtained here and at several points along the creek through the south half of section 2 (14 N., 6 W.). Small outcrops of soft, shelly, yellow-colored sandstone and black shale occur along the creek in sections 35 and 36 (15 N., 6 W.), but the greater part of this area is covered deeply with glacial drift, and the rock in the few exposures has no commercial value.

East of Beech Grove church, through the south half of section 30 (15 N., 5 W.), in Putnam county, thin-bedded to shaly light-gray and yellow sandstone outcrops in several places, the largest exposure being one on the wagon road about 150 yards east of the church, and another on the south bank of the branch just north of Mr. Shonkwiler's barn, about a half mile east of the church. In both places the surface of the sandstone is marked with glacial striæ running S. 25° W. The stone at the top of the exposures is in thin layers one to three inches, but massive at the base and probably massive at the top a short distance back in the bluff. Stone for local use in rough work might be obtained here at little expense.

In the northeast quarter of the southeast quarter of Sec. 30, on the south side of the branch, is an outcrop of six feet of thinly-bedded sandstone of a bright brick red color, variegated in places. While the color is attractive the surface exposure would not indicate sufficient stone of a uniform color to be worked with profit.

There is a fine little chalybeate spring in the south part of Sec. 19 (15 N., 5 W.) on one of the terminal tributaries of Rocky Fork from the north. No rock exposures were observed in this tributary, the slopes being covered with glacial drift. The record of a drilled well in the southeast quarter of the northeast quarter of Sec. 19 (15 N., 5 W.) gives 30 feet of drift and more than 60 feet of sandstone, water having been obtained in the sandstone 90 feet from the surface and 60 feet from the top of the sandstone.

Little Rocky Fork.—The Mansfield sandstone outcrops in large quantity and fine quality on Little Rocky Fork through Sec. 22 (14 N., 6 W.) from the northwest corner to the southeast corner. It outcrops further southeast, in sections 23 and 26, but the best stone, and probably all that has any economic value is in Sec. 22. The stone through the northwest quarter of Sec. 22 is mostly concealed by overlying drift, only a few small ledges of inferior gray ferruginous sandstone being exposed. In a small ravine from the west, about a quarter of a mile south of the school-house, is an outcrop of fissile black shale underlying the sandstone.

A little more than a half mile southeast of the school-house, on the west bank of the creek, in the northwest quarter of the southwest quarter of Sec. 22 (14 N., 6 W.), is an outcrop of handsome red sandstone, probably not surpassed in quality by any in the State. A section of the bluff at this point shows:

five feet high and 25 to 30 feet across under the ledge of sandstone. The stone is not suitable for building purposes.

On the west side of Sec 28 (15 N., 6 W.), in a small branching ravine from the northwest, is an outcrop of the basal chert conglomerate similar to the "peanut rock" at the Mansfield quarry. The conglomerate rests unconformably on the Lower Carboniferous limestone, and is overlain in places by a dull-brown shale. There is very little massive sandstone exposed at this locality. In the northeast quarter of Sec. 28 (15 N., 6 W.). there is considerable limestone exposed, and at intervals for several miles above this the limestone is exposed on both sides of the creek, in some places 50 feet or more in thickness.

The limestone extends up Troutman's Branch more than a mile from the mouth. Good stone for lime burning could be obtained from the bluffs along the south side of the branch in Secs. 21 and 28 (15 N., 6 W.). On a small tributary of Troutman's Branch from the west, in the S. E. quarter of Sec. 20 (15 N., 6 W.) is an outcrop of massive sandstone 30 to 40 feet thick, overlain by 10 to 20 feet of drift, and underlain by 8 to 10 feet of blue-gray shale. Several small springs, highly charged with iron, emerge on the top of the shale at the base of the sandstone, and have formed considerable deposits of iron oxide on the face of the bluff. The lower part of the sandstone contains much iron pyrites, which is probably the source of the iron in the spring water. The sandstone contains too much iron to be valuable for building stone.

Along Troutman's branch, above this, in sections 16, 9, 8, and 5 (15 N., 6 W.), there is very little sandstone exposed, but there is considerable black and drab-colored shale exposed, the largest outcrop being near the middle of the north half of Sec. 16 (15 N., 6 W.), just west of the wagon road and on the east bank of the branch. The shale is here exposed 35 to 40 feet thick, containing a few inches of sandstone and overlain by two to three feet of soil and clay. The shale at the top of the bluff has a dirty yellow color due to oxidation of the iron, while that near the base has a blue-drab color, which is presumably the color of the interior of the bed. In the northeast quarter of Sec. 8 (15 N., 6 W.) the shale, blue-black in color, has a firmer texture and has had a local use for hearths and back walls for fire-places, as it is said to withstand the fire remarkably well.

In a small ravine on the west side of Raccoon creek, in Sec. 16 (15 N., 6 W.), is a horseshoe bluff of massive, coarse-grained, ferruginous yellow and gray sandstone, underlain by 40 to 50 feet of limestone. The stone is covered too deeply by glacial drift (25 to 30 feet) to be quarried.

On a small tributary of Raccoon creek from the northeast, east of the wagon road, in the southeast quarter of Sec. 9 and the northeast quarter of Sec. 16 (15 N., 6 W.), is a deposit of heavy-bedded gray, yellow-spotted sandstone that has been quarried for local use in bridge building. The stone is suitable for small bridges and foundations but is not sufficiently uniform in color for superstructures. It occurs in large quantities and could be quarried cheaply. Near the mouth of this tributary, in the northeast quarter of Sec. 16 (15 N., 6 W.), is a high shale bluff which shows:

Vertical Section in 15 N., 6 W., Section 16.

Yellowish brown shale (weathered)	10 to 12 feet.
Drab shale	12 to 15 feet.
Shaly sandstone	4 in.
Fissile black shale	4 feet.
Coal	4 in.
Lumpy, drab-colored shale (fire-clay)	8 feet.
Limestone	12 in.

In the southwest quarter of Sec. 10, on the north side of Raccoon creek, the Lower Carboniferous limestone outcrops in large quantities and in one place has been quarried for local use.

In the southeast quarter of Sec. 3 (15 N., 6 W.) on the north side of the creek, below the mouth of Limestone branch, is a bold bluff of gray and buff colored sandstone, from which stone for use as grindstones has been obtained in years past. Bridge stone might be obtained here, but as better stone occurs near Portland Mills it will probably never be quarried.

On Limestone branch, the small tributary from the north in Sec. 3 (15 N., 6 W.), sandstone of inferior quality outcrops in several places, resting unconformably on a bed of compact, blue, cherty Lower Carboniferous limestone, which outcrops along the bottom of the valley. The limestone contains much chert and is highly fossiliferous.

Above the mouth of Limestone branch, on the north side of the creek, in Sec. 2 (15 N., 6 W.), there are rugged cliffs, 30 to 40 feet high, of coarse-grained, variegated Mansfield sandstone, which occurs in heavy layers, containing much false bedding and many iron segregations.

In the small branching ravine in the southwest quarter of Sec. 36 and the southeast quarter of Sec. 35 (16 N., 6 W.), on the land of Mr Harbeson and Mr. Miller, there are large exposures of the Mansfield stone. The numerous small ravines have all cut narrow channels into the sandstone, which forms steep to overhanging cliffs on each side, the gullies in places being as narrow as they are deep. The stone contains much false bedding and iron oxide, but there are small areas comparatively free from either which might furnish stone for local use. Such a locality occurs in the northwest quarter of the southwest quarter of Sec. 36 (16 N., 6 W), near the half section line on the north side of the forty acres, where twenty to twenty-five feet of fairly good stone are exposed. In the northeast quarter of the southeast quarter of Sec. 35, in a ravine from the north, is the thickest outcrop observed on the branch, but the stone is too irregularly bedded to have any value. In the south part of the southeast quarter of Sec. 35 (16 N., 6 W.), just north of the wagon road, there is considerable blue-black shale and shale conglomerate exposed, along with thin layers of sandstone.

There is considerable sandstone of inferior quality exposed in a small ravine east of the one mentioned, and nearly parallel with it, in the southwest quarter of Sec. 36 (16 N., 6 W.). A small outcrop of limestone occurs in the southwest corner of this section (Sec. 36).

Ferndale.—On the east side of Raccoon creek no sandstone outcrops of even local importance were observed between Mr. Pruitt's quarry previously described and in the vicinity of Ferndale postoffice in the northwest quarter of Sec. 34 (15 N., 6 W.) About fifty yards south of the postoffice some sandstone has been quarried for local use from the loose bowlders and exposed ledges. The stone has a comparatively uniform coarse grain, but is quite variegated in color, having patches of red-brown, yellow and gray. It is a good, durable stone, suitable for underground foundations.

Sandstone is exposed on each side of Limestone branch* for 100 yards or more below (west of) Ferndale postoffice, with occasional exposures toward the top of the hill. The Lower Carboniferous limestone is exposed along the bottom of the valley from the postoffice to Raccoon creek, and has been quarried at the east end of the bridge to build the approaches to the bridge. It is very fossiliferous about midway between the postoffice and the creek. The limestone is exposed above Ferndale in the southeast quarter of Sec. 27 (15 N., 6 W.) and again in the northwest corner of Sec. 26 and the northeast corner of Sec. 27.

On the hill on the north side of the branch, opposite Ferndale postoffice, the yellow-gray-brown variegated sandstone, ten to twelve feet, lies unconformably on the Lower Carboniferous limestone (St. Louis) and is overlaid by thirty feet or more of bluish argillaceous shale, sandy at the base.

Along Limestone branch above Ferndale, through Sec. 27 (15 N., 6 W.), are extensive outcrops of black shale and gray and variegated sandstone which seem to replace each other in part in different localities, in places the shale predominating, in places the sandstone. In the northeast corner of the section, just south of the east-west wagon road, a light gray fossiliferous sandstone rests unconformably on the Lower Carboniferous limestone and is overlain by a black shale containing coal. Some coal has been mined. The sandstone contains many fossil coal plants,

*This should not be confused with the Limestone branch on the north side of the creek, just below Portland Mills.

in one place a trunk of a *calamites* stem eight or nine inches in diameter being exposed for a length of sixteen feet, with both ends concealed in the sandstone.

No valuable sandstone for building purposes was observed in this locality, as in most places it is more or less variegated in color. In several places within three-quarters of a mile southwest from the northeast corner of Sec. 27 (15 N., 6 W.), along Limestone branch there are exposures of good, durable stone, uniform in grain and structure, but lacking uniformity of color. Good bridge and foundation stone could be obtained here.

Between Limestone branch and Bain branch there are large exposures of limestone, especially prominent near the middle of Sec. 22 (15 N., 6 W.) and the southwest quarter of Sec. 15 (15 N., 6 W.). No sandstone of even local value was observed.

Bain Branch.--On Bain branch sandstone outcrops on the lower course and again near the headwaters, but in the middle course through the north part of sections 13 and 14 (15 N., 6 W.) the slopes are covered with glacial drift and no sandstone is exposed. A small quantity of gray and buff colored sandstone has been quarried in the southeast corner of Sec. 10 (15 N., 6 W.) in the bluff on the south side of the creek, where it occurs in layers eight to sixteen inches thick and is exposed through a thickness of twenty to twenty-five feet, including thin layers of intercalary shale. Ripple-marked sandstone outcrops about 200 yards west of this bluff in the bed of the creek, and shaly sandstone and Lower Carboniferous limestone outcrop along the small tributary from the northeast in the southeast quarter of Sec. 10 and the west side of Sec. 11 (15 N., 6 W.), but there is none of any value.

In the northeast quarter of Sec. 13 and the southeast quarter of Sec. 12 (15 N., 6 W.) at the county line between Parke and Putnam counties is an outcrop of more massive yellow sandstone, which is pyritiferous at the base and underlain by blue and black shale; several small chalybeate springs emerge from this sandstone. The maximum thickness observed in the outcrop was twenty feet. Good, durable bridge stone could be obtained here; the color is not uniform nor pleasing enough for good dimension stone.

There is a low (eight to ten feet) bluff of massive sandstone along the south bank of Raccoon creek in the southwest quarter of Sec. 2 (15 N., 6 W.) which contains some good stone, but it is not so accessible as better stone nearer Portland Mills. The same may be said of similar bluffs along the south bank of the creek in the northeast quarter of Sec. 2. Some yellow ferruginous sandstone outcrops along a small tributary in the southeast quarter of Sec. 2 and the southwest quarter of Sec. 1 (15 N., 6 W.), but it has no economic value. In the northeast quarter of the

W. H. Pruitt's Quarry.—On W. H. Pruitt's farm on the east side of Raccoon creek, in the N. E. quarter of Sec. 5 (14 N., 6 W.), and the N. W. quarter of Sec. 4, is a rounded hill with buff, gray and brown sandstone outcropping on the southwest and north sides. A small quantity of the stone has been quarried on the northwest side of the hill. The quarry has been opened in the brownstone, which, like that at Mansfield, consists of different shades. The prevailing color is a purplish brown with a steel gray lustre, but the general color of the stone is lighter than the Mansfield stone. There is a thickness of about ten feet of the brownstone exposed at the quarry, underlain by buff sandstone and overlain by drift material, which slopes up rapidly to a height of 25 feet or more above the sandstone exposure. How thick the brownstone may be under this drift can not be determined from the surface. No iron secretions, which proved such a serious drawback to the Mansfield stone, were observed at this place; there is a little cross-bedding. The color and texture of the stone are good, and some good stone has been taken out. Whether it can be profitably obtained in quantity depends upon the character and thickness of the brownstone under the drift and the amount of stripping that will be necessary. This could be determined by drilling a few holes on the hill above the quarry opening. The brownstone outcrops also on the south side of the hill, while on the immediate creek bluff on the west end only buff sandstone was observed.

Rocky Fork Branch of Raccoon Creek.—Rocky Fork, with its tributaries, drains nearly all of Jackson township, Parke county (14 N., 6 W.), the head branches extending into the townships north and east. It has cut a network of channels through the massive Mansfield sandstone, exposing that rock in many places. The most valuable stone in the valley is that exposed on Little Rocky Fork in the vicinity of "Fallen Rock" and on "Straight Branch" of Big Rocky in the north part of Sec. 10.

Sandstone is exposed on each side of the creek between the confluence of Big and Little Rocky Forks and that of the main stream with Raccoon creek, the largest exposures being on the west side of the creek. On the east side of the wagon road on the west side of the creek, in the northeast quarter of Sec. 8 and the northwest quarter of Sec. 9 (14 N., 6 W.), the thickness of the sandstone exposure is about 25 feet, of which the upper 12 to 15 feet have a red-brown color like the Mansfield stone. It contains much cross-bedding and many iron blisters. The bottom of the exposure is light colored and contains patches of shale. There is none of it suitable for building stone.

There is an outcrop of similar stone in the southwest quarter of section 9 (14 N., 6 W.), and at intervals between it and the above, but it has no economic value. The same is true of all the stone observed in sections 16 and 15 (14 N., 6 W.). The largest exposures are on a small tributary from the southeast in the northeast quarter of section 15 (14 N., 6 W.), *Section near Fallen Rock on Little Rocky Fork.*

	Feet.
Glacial drift	0 to 15
Buff sandstone	6 to 10
Red sandstone	12 to 15
Red and gray variegated sandstone	8
Buff sandstone	8

The red sandstone has a lighter and brighter shade than the Mansfield stone, is more uniform in color and texture and is free from flaws. It is exposed for a distance of 50 or 60 yards along the bluff, terminating rather abruptly to the northwest in buff and yellow sandstone containing reticulated iron veins and lumps. Along the bluff to the southeast the red stone disappears beneath loose soil and drift material. The next rock bluff in that direction is more than 100 yards distant, and it is of red and yellow variegated stone with too much iron to be of any value. On the opposite side of the creek, northeast from the red stone, the nearest stone is yellow colored and contains much segregated iron oxide. The short limits of the good stone in these three directions is more favorable than otherwise to the probability of finding a greater extent in the remaining direction, namely to the southwest or back into the hill. If the stone extends back into the hill any considerable distance without change in its uniformity, which seems probable, this would prove a valuable deposit. The six to ten feet of buff stone overlying the red ought to more than pay for its removal, and the only stripping that would be expensive would be the drift material. The surface indications are such as to fully warrant investigation.

About the middle of the south half of Sec. 22 (14 N., 6 W.), 60 yards north of the wagon road, a small quantity of red sandstone was quarried from the bottom of the valley several years ago, but the opening is now concealed by the wash from the stream.

In a ravine from the south on the south side of the wagon road in the southwest quarter of Sec. 22, at the "caves," a heavy bed of good sandstone is exposed. The small watercourse has cut a channel 60 to 75 feet deep in the rock, which in two places has yielded more readily to water than elsewhere, and has been undermined, forming a water-fall in the branch and an overhanging cliff ("the cave") on either side. The stone varies in color, buff, yellow, gray, red and variegated occurring. However, the variegated forms a small part of the whole; much gray, yellow and buff stone occurs, uniform in color for a considerable extent. The red was not observed in paying quantities. There is a little cross grain in one place and a little iron in another, and in one place it is somewhat shelly. Nevertheless, there is much good building stone at this locality that could be quarried to advantage if sufficient care was taken in selecting the quarry opening and in classifying the stone after quarrying. While the bed is 70 or 75 feet thick, it is in most places not more than 30 or 40 feet on the face of the bluff.

At "Saltpeter Cave," on the north side of the creek, 150 yards north of east from the ravine above mentioned, is a large exposure of excellent sandstone. The massive bed 40 to 50 feet thick, the base of which contains much pyrite, is underlain by a drab-colored shale 10 feet or more in thickness. The shale and the pyritiferous layer decaying more rapidly have left the more durable massive sandstones projecting in an overhanging bluff which has been cut back by the small stream into a crescent shape. The upper ten feet of this rock has weathered shelly and shows a little cross grain, but the succeeding 30 feet appears uniform in grain and texture but varies in color, gray, buff, red, and variegated occurring with the buff predominating. It is rather coarse grained and contains some mica. The homogeneous texture and the regular bedding of this stone make it a very desirable building stone.

The only exposure of good stone observed on Little Rocky Fork above the "Saltpeter Cave" is in the bluff at the spring across the creek from Fallen Rock. The bluff here is 20 to 25 feet of homogeneous buff-colored sandstone, with smooth, moss-covered face, entirely free from weather seams. Firm rock extends to the top of the bluff, and the slope is very gentle back from the face of the bluffs, so that little stripping would be necessary in quarrying the stone.

The bluff at Fallen Rock and southeast from it on the east side of the creek contains too much iron to be used for building purposes. In this part of the valley there are numerous very large fragments that have broken off from the parent ledge and rolled into the valley. The largest of these, termed Fallen Rock, is probably 15 x 30 x 20 feet. One called Elephant Rock, from its shape, contains much iron oxide, and weathers very irregularly.

There is a small outcrop of black shale at the base of the massive sandstone on the west side of a small ravine from the north at the section line between sections 22 and 23 (14 N., 6 W.), in the southeast quarter of Sec. 22. There is another small exposure of black shale in the northwest quarter of Sec. 26. Sandstone outcrops in the southwest quarter of section 23 and the north part of section 26 (14 N., 6 W.), but the exposures are small and have no economic value. That in the first locality named resembles the Portland stone, but has too much overlying glacial material to be worked with profit.

West side of Raccoon Creek between Mansfield and Portland Mills.—Between Mansfield and Portland Mills sandstone adapted to local use outcrops in several places. In the northwest quarter Sec. 33 (15 N., 6 W.), west of the wagon road, is a low bluff of massive sandstone 15 to 20 feet high, cross-grained and ferruginous. There is a natural bridge near the southwest end of the bluff, where a small ravine has cut a channel about five feet high and 25 to 30 feet across under the ledge of sandstone. The stone is not suitable for building purposes.

On the west side of Sec 28 (15 N., 6 W.), in a small branching ravine from the northwest, is an outcrop of the basal chert conglomerate similar to the "peanut rock" at the Mansfield quarry. The conglomerate rests unconformably on the Lower Carboniferous limestone, and is overlain in places by a dull-brown shale. There is very little massive sandstone exposed at this locality. In the northeast quarter of Sec. 28 (15 N., 6 W.). there is considerable limestone exposed, and at intervals for several miles above this the limestone is exposed on both sides of the creek, in some places 50 feet or more in thickness.

The limestone extends up Troutman's Branch more than a mile from the mouth. Good stone for lime burning could be obtained from the bluffs along the south side of the branch in Secs. 21 and 28 (15 N., 6 W.). On a small tributary of Troutman's Branch from the west, in the S. E. quarter of Sec. 20 (15 N., 6 W.) is an outcrop of massive sandstone 30 to 40 feet thick, overlain by 10 to 20 feet of drift, and underlain by 8 to 10 feet of blue-gray shale. Several small springs, highly charged with iron, emerge on the top of the shale at the base of the sandstone, and have formed considerable deposits of iron oxide on the face of the bluff. The lower part of the sandstone contains much iron pyrites, which is probably the source of the iron in the spring water. The sandstone contains too much iron to be valuable for building stone.

Along Troutman's branch, above this, in sections 16, 9, 8, and 5 (15 N., 6 W.), there is very little sandstone exposed, but there is considerable black and drab-colored shale exposed, the largest outcrop being near the middle of the north half of Sec. 16 (15 N., 6 W.), just west of the wagon road and on the east bank of the branch. The shale is here exposed 35 to 40 feet thick, containing a few inches of sandstone and overlain by two to three feet of soil and clay. The shale at the top of the bluff has a dirty yellow color due to oxidation of the iron, while that near the base has a blue-drab color, which is presumably the color of the interior of the bed. In the northeast quarter of Sec. 8 (15 N., 6 W.) the shale, blue-black in color, has a firmer texture and has had a local use for hearths and back walls for fire-places, as it is said to withstand the fire remarkably well.

In a small ravine on the west side of Raccoon creek, in Sec. 16 (15 N., 6 W.), is a horseshoe bluff of massive, coarse-grained, ferruginous yellow and gray sandstone, underlain by 40 to 50 feet of limestone. The stone is covered too deeply by glacial drift (25 to 30 feet) to be quarried.

On a small tributary of Raccoon creek from the northeast, east of the wagon road, in the southeast quarter of Sec. 9 and the northeast quarter of Sec. 16 (15 N., 6 W.), is a deposit of heavy-bedded gray, yellow-spotted sandstone that has been quarried for local use in bridge building. The stone is suitable for small bridges and foundations but is not sufficiently uniform in color for superstructures. It occurs in large quantities and could be quarried cheaply. Near the mouth of this tributary, in the northeast quarter of Sec. 16 (15 N., 6 W.), is a high shale bluff which shows:

Vertical Section in 15 N., 6 W., Section 16.

Yellowish brown shale (weathered)	10 to 12 feet.	
Drab shale	12 to 15 feet.	
Shaly sandstone		4 in.
Fissile black shale	4 feet.	
Coal		4 in.
Lumpy, drab-colored shale (fire-clay)	8 feet.	
Limestone		12 in.

In the southwest quarter of Sec. 10, on the north side of Raccoon creek, the Lower Carboniferous limestone outcrops in large quantities and in one place has been quarried for local use.

In the southeast quarter of Sec. 3 (15 N., 6 W.) on the north side of the creek, below the mouth of Limestone branch, is a bold bluff of gray and buff colored sandstone, from which stone for use as grindstones has been obtained in years past. Bridge stone might be obtained here, but as better stone occurs near Portland Mills it will probably never be quarried.

On Limestone branch, the small tributary from the north in Sec. 3 (15 N., 6 W.), sandstone of inferior quality outcrops in several places, resting unconformably on a bed of compact, blue, cherty Lower Carboniferous limestone, which outcrops along the bottom of the valley. The limestone contains much chert and is highly fossiliferous.

Above the mouth of Limestone branch, on the north side of the creek, in Sec. 2 (15 N., 6 W.), there are rugged cliffs, 30 to 40 feet high, of coarse-grained, variegated Mansfield sandstone, which occurs in heavy layers, containing much false bedding and many iron segregations.

In the small branching ravine in the southwest quarter of Sec. 36 and the southeast quarter of Sec. 35 (16 N., 6 W.), on the land of Mr Harbeson and Mr. Miller, there are large exposures of the Mansfield stone. The numerous small ravines have all cut narrow channels into the sandstone, which forms steep to overhanging cliffs on each side, the gullies in places being as narrow as they are deep. The stone contains much false bedding and iron oxide, but there are small areas comparatively free from either which might furnish stone for local use. Such a locality occurs in the northwest quarter of the southwest quarter of Sec. 36 (16 N., 6 W), near the half section line on the north side of the forty acres, where twenty to twenty-five feet of fairly good stone are exposed. In the northeast quarter of the southeast quarter of Sec. 35, in a ravine from the north, is the thickest outcrop observed on the branch, but the stone is too irregularly bedded to have any value. In the south part of the southeast quarter of Sec. 35 (16 N., 6 W.), just north of the wagon road, there is considerable blue-black shale and shale conglomerate exposed, along with thin layers of sandstone.

There is considerable sandstone of inferior quality exposed in a small ravine east of the one mentioned, and nearly parallel with it, in the southwest quarter of Sec. 36 (16 N., 6 W.). A small outcrop of limestone occurs in the southwest corner of this section (Sec. 36).

Ferndale.—On the east side of Raccoon creek no sandstone outcrops of even local importance were observed between Mr. Pruitt's quarry previously described and in the vicinity of Ferndale postoffice in the northwest quarter of Sec. 34 (15 N., 6 W.) About fifty yards south of the postoffice some sandstone has been quarried for local use from the loose bowlders and exposed ledges. The stone has a comparatively uniform coarse grain, but is quite variegated in color, having patches of red-brown, yellow and gray. It is a good, durable stone, suitable for underground foundations.

Sandstone is exposed on each side of Limestone branch* for 100 yards or more below (west of) Ferndale postoffice, with occasional exposures toward the top of the hill. The Lower Carboniferous limestone is exposed along the bottom of the valley from the postoffice to Raccoon creek, and has been quarried at the east end of the bridge to build the approaches to the bridge. It is very fossiliferous about midway between the postoffice and the creek. The limestone is exposed above Ferndale in the southeast quarter of Sec. 27 (15 N., 6 W.) and again in the northwest corner of Sec. 26 and the northeast corner of Sec. 27.

On the hill on the north side of the branch, opposite Ferndale postoffice, the yellow-gray-brown variegated sandstone, ten to twelve feet, lies unconformably on the Lower Carboniferous limestone (St. Louis) and is overlaid by thirty feet or more of bluish argillaceous shale, sandy at the base.

Along Limestone branch above Ferndale, through Sec. 27 (15 N., 6 W.), are extensive outcrops of black shale and gray and variegated sandstone which seem to replace each other in part in different localities, in places the shale predominating, in places the sandstone. In the northeast corner of the section, just south of the east-west wagon road, a light gray fossiliferous sandstone rests unconformably on the Lower Carboniferous limestone and is overlain by a black shale containing coal. Some coal has been mined. The sandstone contains many fossil coal plants,

*This should not be confused with the Limestone branch on the north side of the creek, just below Portland Mills.

in one place a trunk of a *calamites* stem eight or nine inches in diameter being exposed for a length of sixteen feet, with both ends concealed in the sandstone.

No valuable sandstone for building purposes was observed in this locality, as in most places it is more or less variegated in color. In several places within three-quarters of a mile southwest from the northeast corner of Sec. 27 (15 N., 6 W.), along Limestone branch there are exposures of good, durable stone, uniform in grain and structure, but lacking uniformity of color. Good bridge and foundation stone could be obtained here.

Between Limestone branch and Bain branch there are large exposures of limestone, especially prominent near the middle of Sec. 22 (15 N., 6 W.) and the southwest quarter of Sec. 15 (15 N., 6 W.). No sandstone of even local value was observed.

Bain Branch.—On Bain branch sandstone outcrops on the lower course and again near the headwaters, but in the middle course through the north part of sections 13 and 14 (15 N., 6 W.) the slopes are covered with glacial drift and no sandstone is exposed. A small quantity of gray and buff colored sandstone has been quarried in the southeast corner of Sec. 10 (15 N., 6 W.) in the bluff on the south side of the creek, where it occurs in layers eight to sixteen inches thick and is exposed through a thickness of twenty to twenty-five feet, including thin layers of intercalary shale. Ripple-marked sandstone outcrops about 200 yards west of this bluff in the bed of the creek, and shaly sandstone and Lower Carboniferous limestone outcrop along the small tributary from the northeast in the southeast quarter of Sec. 10 and the west side of Sec. 11 (15 N., 6 W.), but there is none of any value.

In the northeast quarter of Sec. 13 and the southeast quarter of Sec. 12 (15 N., 6 W.) at the county line between Parke and Putnam counties is an outcrop of more massive yellow sandstone, which is pyritiferous at the base and underlain by blue and black shale; several small chalybeate springs emerge from this sandstone. The maximum thickness observed in the outcrop was twenty feet. Good, durable bridge stone could be obtained here; the color is not uniform nor pleasing enough for good dimension stone.

There is a low (eight to ten feet) bluff of massive sandstone along the south bank of Raccoon creek in the southwest quarter of Sec. 2 (15 N., 6 W.) which contains some good stone, but it is not so accessible as better stone nearer Portland Mills. The same may be said of similar bluffs along the south bank of the creek in the northeast quarter of Sec. 2. Some yellow ferruginous sandstone outcrops along a small tributary in the southeast quarter of Sec. 2 and the southwest quarter of Sec. 1 (15 N., 6 W.), but it has no economic value. In the northeast quarter of the southeast quarter of Sec. 2 on this branch is one of the finest chalybeate springs observed in this region.

Nelson Branch.—On a small branch in the middle and southeast quarter of Sec. 1 (15 N., 6 W.), locally known as the Nelson branch, is one of the most promising sandstone outcrops in the Raccoon valley. The small watercourse has cut a deep gorge back into the sandstone and limestone for a half mile from the creek, and it is near the upper limit of this deep gorge, just below the upper waterfall, that the largest exposure of the sandstone occurs. The bluff is forty-five to fifty feet high, the lower twelve to fifteen feet being concealed by the huge angular blocks that have broken off and tumbled down from the top of the ledge, some of which boulders are not less than fifty feet across. The upper part of the cliff is perpendicular, smooth, seamless and moss-covered. The stone is apparently solid to the top of the cliff, with very little overlying waste material. The color of the stone as indicated by the boulders in the talus is somewhat variegated, with gray the prevailing color, streaked in places with buff and red. The perpendicular face of the cliff is not accessible and it is not possible from the base of the cliff to see how much of the stone is variegated, but the absence of iron segregations, the freedom from seams and the uniformity of texture would indicate a considerable uniformity of color, and the outcrop would indicate large quantities of good, durable building stone.

The sandstone outcrops for nearly 100 yards above the falls (southeast), and in large quantities along the branch between the upper and lower falls, the best stone occurring along the south or west side of the branch.

The lower fall, which is near the middle of the section, is about thirty feet high and in the Lower Carboniferous limestone underlying the sandstone. The limestone outcrops along the branch below the falls to Raccoon creek, but no sandstone of economic importance was observed below the lower fall.

Portland Mills.—There are quite marked local variations in the stratigraphy in the immediate vicinity of Portland Mills. Nelson's branch, described above, where not less than fifty feet of the massive Mansfield sandstone occurs, underlain by shaly and cherty Lower Carboniferous limestone, is scarcely more than a half mile southwest of the village. Immediately east of the village is a high cliff of blue-black shale ("The Blue Bluff") which is eighty feet or more in thickness. The shale underlies the town in part and extends probably a quarter of a mile west of the town, the glacial drift concealing the western limits. North of the village, on the north side of Raccoon creek, the red and gray Mansfield sandstone occurs in a bed 100 feet thick, underlain by an impure limestone. West of north from the village, about 100 yards west of the school-house, is another exposure of the blue shale (yellow and brown on the weathered surface) fifty feet or more in thickness. East, southeast and northeast of the village are considerable exposures of compact, blue limestone of Lower Carboniferous age. Three fourths of a mile northeast are fine outcrops of the basal conglomerate between the Lower and Upper Carboniferous systems.

In the heavy sandstone deposit on the north side of the creek, opposite the village, a quarry has recently been opened in the brownstone by the Portland Mills Red Sandstone Co., but at the present writing (December, 1895) no stone has been shipped, and but little more than preliminary work has been done. The soil and waste material have been stripped from a half acre or more, and in places opened to a depth of three or four feet. The surface stone so far removed lacks uniformity of color; besides the different shades of brown there are a few irregular patches of gray. Part of the variegation is probably due to weathering influences, the leaching of the color by organic acids. In places there are scattered pebbles of shale, sandstone, and iron which, while not abundant, ruin some of the stone for mill blocks. The brownstone ranges from twenty-five to fifty feet in thickness, with no sharp line of parting between it and the underlying gray and yellow sandstone. The total thickness of the sandstone from the highest exposure, 100 yards or so north of the quarry to the underlying limestone at the creek, is 100 feet. There can be no doubt of the great quantity of stone at this locality and where it is uniform in color and free from the pebbles it is a handsome and durable stone. There will be some waste material, but the good stone, if properly selected, can be used with perfect safety. A microscopic examination shows the brownstone to consist almost wholly of white quartz grains in a cement of red iron oxide. (See fig. 2 on plate 12.) Partial chemical analysis made by Dr. Baker at Greencastle shows this stone to have a higher per cent. of iron oxide cement than that from other localities.* There are two glacial pot-holes in the new quarry opening, one about four feet and the other six feet across and six to eight feet deep.

West of the quarry and facing the mill pond is a bluff forty to fifty feet high, of massive gray and buff sandstone with a few feet of red stone in places along the top. Along the bottom of this bluff and at the west end, the stone is very much cross-grained and streaked in places with iron ore. Through a thickness of twenty feet or more at the upper part of the bluff toward the east end, the stone is uniform in texture and would furnish good building stone. Immediately north of the mill and thence west the stone has little, if any, commercial value.

East of the quarry the stone outcrops along the creek to the bluffs of Byrd branch, a distance of a quarter of a mile.

---

* See tables in the final chapter for analyses.

Byrd Branch.—Sandstone is exposed in several places along Byrd branch through Sec. 31 (16 N., 5 W.), but so far as observed contains too much iron and false bedding to have any commercial value. Near the middle of the north half of Sec. 31 (16 N., 5 W.), the basal conglomerate, marking the unconformity between the Lower Carboniferous limestone and the Mansfield sandstone of the Coal Measures, occurs on each side of the branch. It consists of large angular and sub-angular chert pebbles varying in size from one inch to eight or ten inches in diameter, much of it being fossiliferous and all bound together by a cement of sand, clay, and lime. The conglomerate is eight to ten feet thick and is overlain by the coarse-grained yellow Mansfield sandstone, which at the base contains many fossil coal plants and segregations of iron oxide.

In the northeast quarter of Sec. 31 (16 N., 5 W.), 100 yards south of the forks of the road, there appears to be a fault in the strata, as shown on the accompanying figure. (Fig. 1.) While there is a possibility of this being a case of unconformity by erosion, the abrupt change looks more like a misplacement of the layers.

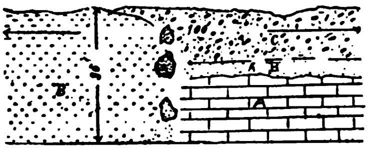


Fig. 1. Section of fault on Byrd branch near Portland Mills.

A—Lower Carboniferous limestone.
B—Mansfield sandstone.
C—Glacial drift.

Along Byrd branch, underlying the sandstone, is a bed of Lower Carboniferous compact blue limestone which occurs in regular strata eight to twenty inches thick, evenly bedded and regularly jointed, weathering out in rectangular blocks two or three feet across. Good foundation stone and stone suitable for making lime could be obtained from this limestone. Similar limestone outcrops in large quantities further east along both sides of Raccoon creek through the southeast quarter of section 31, the south part of Sec. 32 (16 N., 5 W.), and the north parts of sections 5 and 6 (15 N., 5 W.).

Between Portland Mills and Ramp Creek.—There is a marked change in the strata in the ravine from the south in the northwest quarter of Sec. 6 (15 N., 5 W.); near the head of the ravine the massive sandstone occurs twenty-five feet or more in thickness underlain, as seen in passing down the ravine, by a shaly conglomerate ten feet, drab-colored shale twenty feet, and limestone twenty feet, while near the mouth of the ravine the drab colored shale is eighty feet thick, apparently replacing all the other strata, as there is no evidence of faulting. This immense bed of shale, if it proves of proper quality for paving brick, as the outcrop would indicate, will no doubt be used when transportation facilities are afforded. The cost of mining it would be merely nominal.

Through the north central part of Sec. 6 (15 N., 5 W.) south of Raccoon creek are several ravines that have cut channels through the massive sandstone and into the underlying limestone, the latter exposed on the lower course and the largest exposure of the sandstone being around the heads of the ravines, where it is forty to fifty feet in thickness, but too variable in color and texture to have much value as a building stone. Small quantities of coal occur in the bed of shale underneath the sandstone and it has been mined for local use in the southwest quarter of Sec. 5 (15 N., 5 W.).

Large quantities of black shale, with small quantities of coal and some sandstone, occur along the Beck branch in the east side of Sec. 4 (15 N., 5 W.).

Along the south side of Raccoon creek through Sec. 33 (16 N., 5 W.), the massive Mansfield sandstone outcrops in a low cliff along the bank of the creek. In places the stone is homogeneous and exposes an even, regular weathered surface. In many places there are segregations of the iron oxide which cause the stone to weather unevenly, and which give it a variegated color. Good stone in limited quantities could be obtained in different places along the bluff.

Near the middle of the west half of Sec. 33 (16 N., 5 W.) on the north side of the creek the sandstone forms a high steep bluff on the creek bank, at the upper end of which a small branching ravine has cut numerous gullies exposing large quantities of the stone. Southwest from this point, along the bluff small quantities of sandstone have been quarried for local use.

Near the middle of the north part of Sec. 33 and the south of Sec. 28 (16 N., 5 W.) the Lower Carboniferous limestone outcrops at a higher level than the sandstone along the creek both south and east of it. Some of the limestone has been quarried. Limestone containing considerable chert outcrops along the ravine east of the wagon road in the southeast quarter of Sec. 28 (16 N., 5 W.) on the north side of the creek, and in Sec. 34 on the south side of the creek. On the south bank of the creek just east of the wagon bridge is a perpendicular cliff forty-five feet high of the massive sandstone, which is variegated in color and lacks uniformity in texture, in some places containing streaks of iron oxide, and in places patches of coarse conglomerate. There is a similar bold bluff of the sandstone one-half mile northeast of the bridge on the creek bluff and in a small ravine from the east, where the stone is more uniform in composition and would furnish good bridge and foundation stone where the overlying drift is not too thick to prevent its use.

On the opposite or west side of the creek in the southwest quarter of Sec. 27 (16 N., 5 W.) the sandstone outcrop measures 55 to 60 feet in thickness, and is quite variable in texture. In some places it is homogeneous in color and texture with a smooth weathered exposure, and, within a few yards, it will show much false bedding, iron secretions and variegated color. Good stone could be obtained here by observing care in selecting the opening for the quarry.

Ramp Creek.—The only outcrop of sandstone of any note on Ramp creek is at Blakesburg in the northwest quarter of Sec. 25 (16 N., 5 W.), and that has very little, if any, economic value. It is interesting from a scientific standpoint in showing a marked unconformity between the sandstone and the underlying Lower Carboniferous limestone as shown on the accompanying figure (Fig. 2). The sandstone is nearly

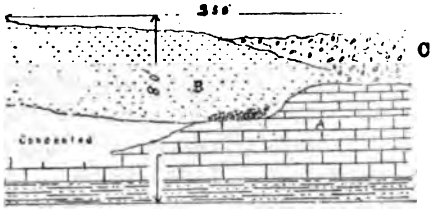


Fig. 2. Section of the bluff at Blakesburg.

A—Lower Carboniferous limestone.
B—Carboniferous (Mansfield) sandstone.
C—Glacial drift.

forty feet in thickness, and contains at the base a coarse conglomerate of chert pebbles from the Lower Carboniferous limestone.

The underlying hard, durable, crystalline limestone has been quarried for local use on each side of Ramp creek 100 yards or more above the sandstone bluff.

A small outcrop of sandstone was reported near the middle of the south half of Sec. 26 (16 N., 5 W.).

Big Raccoon Creek above Ramp Creek.—The only outcrop of the Mansfield sandstone of any economic value in the Raccoon valley above Ramp creek is at what is known as the Snake Den, on Mr. Long's place in the northeast quarter of Sec. 15 (16 N., 5 W.), where the sandstone is 65 feet thick and overlain by glacial drift. It is gray and buff in color, and, for the most part, of uniform texture; a little cross-grained and ferruginous in a few places. There is a great deal of good building stone at this locality, but only a limited quantity could be obtained with profit owing to the heavy bed of overlying drift.

There is a small outcrop of Mansfield stone half a mile east of the Snake Den, on the south side of the creek in the north part of Sec. 14 (16 N., 5 W.), but it has no economic value.

Limestone outcrops in several places along the creek and on the tributaries in the upper part of the Raccoon Valley, some of it being of good quality, but occurring in limited quantity; it has been quarried in the north part of Sec. 2 (16 N., 5 W.).

In the north part of section 14, the west part of section 12 and the east side of section 1 (16 N., 5 W.), and elsewhere in this vicinity is a fine-grained, impure, drab-colored sandstone that is apparently the equivalent of the sandstone at Riverside and that on Big Walnut creek, east of Bainbridge. It has been quarried to some extent along the I., D. & W. R. R., one-fourth mile west of Raccoon Station, and was used in the piers of the railroad bridge on the creek, east of the station, but it has been found necessary to replace it in part, as it began to crumble badly. No resources were available for having any tests made on this stone, but an examination of the outcrops would indicate a stone fairly homogeneous in texture and color, but containing too much clay and iron pyrites to stand exposure in most places. For indoor work or for foundations of small buildings it might be used with safety.

Limestone and drab-colored sandstone outcrops are to be expected about the headwaters of Raccoon creek, but no exploration of the valley north of the I., D. & W. R. R. was made by the writer.

Little Raccoon Creek.—Little Raccoon Creek valley was not explored below Sand Creek station in Sec. 3 (15 N., 7 W.). Citizens of that vicinity report no outcrop below that point. If any does occur it is liable to be of more recent age than the Mansfield sandstone.

The lowest exposure of the Mansfield sandstone observed on the creek is that near the middle of the east half of Sec. 2 (15 N., 7 W.) where the stone has been quarried to some extent. The total thickness of the exposure varies from thirty to thirty-five feet in layers, from one inch to four feet thick. The color is variegated, brown at the base of the exposure, gray and brown banded near the top, in places pepper-and-salt appearance caused by the small black and brown specks of iron oxide in the gray stone.

The above is but one of several small quarries in this vicinity, from some of which stone has been shipped by rail to Logansport. Another quarry, and the smallest of the lot, is on the bluff a quarter of a mile east of the creek, just south of the wagon road, where the stone is gray and brown variegated, too much variegated to be of value for building stone. It would make a good bridge or foundation stone.

Another and larger quarry opening is on the small, rounded hill in the southeast quarter of Sec. 35 (16 N., 7 W.) on the east bank of the creek and 150 yards north of the wagon road. The stone has been quarried near the top of the small, rounded hill, which covers four or five acres. The color is gray, with yellow and brown patches, and in a number of places is cross-grained. There is not sufficient uniformity of color or grain for good building stone, but excellent bridge stone might be obtained.

Another one of these quarries and the one now in operation (April, 1895), is the brownstone quarry on the east side of the creek in the northeast quarter of Sec. 35 (16 N., 7 W.). The stone is a nearly uniform brown, there being some variation in shade, as in the Mansfield quarry; in fact, the stone in grain, color, and texture is very much like the Mansfield stone. It differs in not having the numerous iron blisters and in being much more shelly on the outcrop.

A great deal of work has been done here and much material removed, most of which has been waste. A little good stone has been obtained and there is more in sight, yet at present the good stone is but a small per cent. of the waste and will continue so for some time. How far it is back in the bluff to the sound stone can not be told with certainty from the present opening. The most economical method of testing such a locality would be with the core drill, which would show whether the stone is solid or not back from the bluff, and if it should prove so, the cheapest way to work it would be from the top of the flat. If the drill would show that the rock back from the bluff continues shelly it would save all the work now being done at great expense. The face of the quarry shows thirty-seven feet of sandstone underlain by a blue shale. The lower ten feet of sandstone are very shelly. The remainder shows some good stone, a few feet at the top showing numerous gray and yellow patches, caused probably by the red iron oxide being leached out in part or reduced to the lower oxide by the infiltrating waters from the overlying soil.

The occurrence of so much shelly material on the bluff at this point might at first suggest the thought that the stone is inherently less durable in its composition and make-up, than in other more solid outcrops, such as those at Mansfield and at Portland Mills, but this is not necessarily the case, as the way the bluff faces, the amount and nature of the overlying and underlying material and the relation to the creek channel have something more to do with the nature of the outcrop than the composition of the stone. This quarry is on the south-west slope, the most trying of all, and in most places in this part of the State the slopes facing south or west will have no rock outcrops, even where the north and east slopes have many rocky bluffs.

Around the point of the hill, east from the quarry opening, the red color of the sandstone changes to a variegated and gray. There is a similar change in color in the small ravines north of the quarry.

While at the quarry there are scarcely any iron secretions, less than one hundred yards north of the quarry, along the face of the bluff there is a great deal of segregated iron oxide accompanied by much false bedding.

Ray Branch, a small tributary of Raccoon creek from the northeast just below the quarry, has a few outcrops of yellow, shelly sandstone and some shale in some of its terminal ravines in the northwest quarter of section 31 and the southeast quarter of section 30 (16 N., 8 W.), but none valuable for building stone. The lower part of the valley is wide and the slopes covered with drift, except the sandstone quarries described above.

On the *Miller* or *Cumberland Branch*, in Sections 1, 3, and 12 (15 N., 7 W.), and Sections 6 and 7 (15 N., 6 W.), there are some heavy sandstone ledges exposed. At the mouth of the branch, in the northeast quarter of Sec. 2 (15 N., 7 W.) the sandstone occurs in bluffs on each side of the creek, much of it false bedded and ferruginous, yet in a few places sufficiently uniform for good bridge stone. On the east side of the south prong of the branch, in the northeast quarter of section 12, and again in the southeast quarter of Sec. 12 (15 N., 7 W.) the yellow sandstone has been quarried in small quantities for local use. There is a great deal of inferior sandstone exposed in this section, and while in some places the quality is all right for an average building stone, the overlying drift material is too heavy to permit its being quarried in any great quantity. It is underlain in places by black shale and coal. The latter has been mined in small quantities in one place.

Along the east prong of Miller Branch, in Sec. 1 (15 N., 7 W.), and Sec. 6 (15 N., 6 W.), the sandstone ledge is twenty-five to forty feet thick, and in a few places the exposure is even-faced, sharp angled, lichen-covered and evenly bedded, indicating a good durable building stone. The color is yellow gray. There is a coal bank in this ravine in the northwest quarter of Sec. 6 (15 N., 6 W.), east of the heavy sandstone outcrop, and the black shale is exposed in several places, both east and west from the sandstone bluffs.

Southwest of Judson, on the west side of Little Raccoon creek, the yellow Mansfield sandstone of inferior quality outcrops in the bluff west of the wagon road, the maximum thickness measured being forty feet. In the small tributary from the north, in the northeast quarter of section 26, and the southeast quarter of Sec. 23 (16 N., 7 W.), much yellow and gray sandstone is exposed. Close to the section line between the two sections some stone has been quarried, which is soft and easily worked, but contains too much iron for suitable building stone. Black shale and coal occur underneath the sandstone.

In the small tributary from the northwest on the north side of Judson, in the northwest quarter of Sec. 24 (16 N., 7 W.), gray and yellowish brownstone has been quarried for local use. The dull, variegated color injures its use for building stone. The face of the quarry opening is about twenty-five feet with several feet of overlying drift. The stone is free from iron secretions; but there are a few weather seams, due, in large measure, to the powder used in blasting. There is a large quantity of stone exposed in this ravine, much of it suitable for bridges and foundations.

On the east side of Little Raccoon creek, between Judson and Guion, the Mansfield sandstone outcrops in large quantities. From the wagon road, near the middle of the west side of Sec. 19 (16 N., 6 W.), to Mr. Strong's house, near the middle of Sec. 18 (16 N., 6 W.), there is a continuous ledge of sandstone, the thickness of the exposure varying from 5 to 25 feet. The most valuable building stone is about one quarter of a mile north of the wagon road in the northwest quarter of Sec. 19 (16 N., 6 W.), where the gray and buff sandstone is 15 to 20 feet thick in evenly bedded layers three to five feet thick, the surface smooth and the corners sharp and angular. There is very little covering back from the face of the bluff for 100 feet or more. Abundance of good building stone for heavy masonry could be obtained here. Further north, through Sec. 18 (16 N., 6 W.), the quality of the stone is not so good, yet good foundation or bridge stone could be obtained in a number of places.

Near the middle of the south half of Sec. 18 (16 N., 6 W.) is a small outcrop of shelly limestone at the base of the bluff on the creek bank where lime for local use was burnt several years ago.

Along the small tributary from the southeast in the southeast quarter of Sec. 18, south of Mr. Strong's home, red sandstone was quarried to some extent a few years ago. The face of the quarry is 12 to 15 feet, the upper 3 to 5 feet having a bright red color, the remainder of the bed being gray, or yellow-brown. It is underlain by 15 to 20 feet of black shale. The sandstone lacks uniformity both in color and structure, and while there is considerable nice building stone, it is doubtful if it could be quarried with profit unless the coarse rubble stone could be disposed of with profit.

The North Prong of Little Raccoon Creek.—There is no valuable sandstone on the north prong of Little Raccoon creek. The Mansfield sandstone is exposed on the east bank of the creek at the railway bridge at Guion, where it was quarried for the bridge abutment; in the railway cut, 100 yards or more east of the creek where the stone is brown in color, but too shelly to be valuable; in the small tributary from the northwest at the school-house just north of Guion; on the south and east side of the creek in the southwest and southeast quarters of Sec. 5 (16 N., 6 W.), in the small ravines from the northwest in the northwest quarter of Sec. 5, where there is a single small outcrop of yellow sandstone; in a small tributary on the west side of Sec. 34 (17 N., 6 W.), and on both sides of the creek in the east side of Sec. 34 and the west side of Sec. 35, which is the uppermost exposure of the sandstone observed on this creek.

There is a large quantity of Lower Carboniferous limestone exposed in Sec. 34 (17 N., 6 W.) on both the main creek and the tributary from the north On the west bank of the creek just below the mouth of this tributary is a big limestone quarry now abandoned where a great deal of lime was burned a few years ago. There is a small outcrop of limestone about half a mile west of Waveland and it probably underlies the drift in the valley above Waveland. For a distance of two miles above Waveland the slopes are covered with glacial drift, and the valley was not explored further east.

South Prong of Little Raccoon Creek.—The Mansfield sandstone outcrops in six different places in the valley of the south prong of Little Raccoon creek. The first exposure found in ascending the valley is in 16 N., 6 W., Sec. 17, the northwest quarter, about 150 yards north of the creek, where it first appears as thin-bedded, somewhat ferruginous sandstone. It occurs in heavier layers in the small ravine at the spring but weathers very irregularly. It is yellow-brown to red-brown in color and in the creek just south of the spring is a massive ledge of yellowish brown sandstone, but it is all too impure for good building stone

On the south side of the creek in the ravine from the south in the S. W. quarter of Sec. 17 is an outcrop of sandstone from fifteen to twenty-five feet thick in the bluffs along each side of the ravine. The upper part of the bed is coffee-colored to reddish brown, the lower part of the bed a yellowish brown color. The upper part is evenly bedded, two to four feet thick in places but having weather seams, the lower part shaly and disintegrating in places. The weathered boulders are thin; angular and hard, and there are no large boulders. Mr. Strong says that stone was quarried here 24 years ago by a Chicago firm and several carloads shipped, but the industry was soon discontinued as they claimed the freight rates were so high that the stone could not be quarried with profit

The next outcrop on the south prong of Little Raccoon creek is near the middle of the north half of Sec. 17 (16 N., 6 W.) where the rock is exposed on both sides of the creek and on the south side of the small branch from the northeast. On the branch side of the hill the rock is shaly on the outcrop but on the creek it forms a massive ledge eight to ten feet thick.

There is a larger exposure of the sandstone in the southeast quarter of Sec. 17 where it forms a precipitous bluff on the south bank of the creek; the Lower Carboniferous limestone appears on the east (north) bank a short distance (75 yards) below the sandstone cliff and forms a low retreating bluff twenty-five to thirty feet high along the east side of the creek through the southeast quarter of Sec. 17, while the sandstone forms a perpendicular bluff along the west side for about twenty-five yards to near the point where the road crosses the creek, where the limestone outcrops on both sides of the creek. There is a short interval of a few yards at this point between the sandstone bluff and the limestone which is concealed by soil and debris so that the contact of the two formations is not shown. The discordance in bedding here is to all appearance due to unconformity by erosion. The rocks seem in no place broken or much disturbed.

The limestone has been quarried for local use on the east side of the creek in the southeast quarter of the southeast quarter of Sec. 17 (16 N., 6 W.).

On the branch from the south, west of Parkeville, 150 yards north of the gravel road at the school-house in the northeast quarter of Sec. 20 (16 N., 6 W.), there is an outcrop of brown coffee-colored sandstone with light gray spots, varying in places to a more reddish brown color. It extends along the bottom of the branch for 100 yards or more, exposed in places six or eight feet, in thin-bedded to shaly layers one to two inches thick. It contains considerable brown hematite in places, in one place in a curious chain-like form.

The wells at Parkeville are twenty to forty feet deep, and find water in a bed of gravel.

There are two outcrops of blue-gray to black shale northeast of Parkeville in Sec. 2 (16 N., 6 W.), both on the creek bank, one near the middle of the north half of the section, the other in the northeast quarter.

At the latter point the fifteen to twenty feet of the shale exposed in the bluff on the south bank of the creek is quite fissile and micaceous, near the base containing several thin layers of micaceous sandstone.

The largest outcrop of sandstone observed on this branch of Little Raccoon creek is the uppermost one which occurs in Sec. 22 (16 N., 6 W.), the southwest quarter, and extending into Sec. 27, the northwest quarter. The rock outcrops on both sides of the creek and in the creek bed, but the largest exposure is in the perpendicular bluff in the south and west side, which is known locally as the "Snake Den." The thickness of the rock exposed is forty feet, being overlain by drift and underlain by a gray to black shale. The shale outcrops in the creek bed near the lower end of the bluff and a quarter of a mile up the creek above the upper end of the bluff.

The sandstone in this bluff is very irregularly bedded and ferruginous, and weathers with a very uneven face; the cross bedding is quite pronounced in many places, and the iron in the form of limonite layers occurs in layers, sometimes along the true bedding planes, sometimes along the false bedding planes. Near the upper end of the outcrop the rock is evenly but thinly bedded and has been quarried a little for local use.

While there is abundance of sandstone in this locality, it is too imperfect to have more than a local use.

No sandstone was observed on the south prong of Little Raccoon creek above Sec. 27 (16 N., 6 W.). The only rock exposure observed above this point is a small outcrop of limestone in the southeast quarter of Sec. 8 (16 N., 5 W.), a mile and a half south of Russellville, this part of the valley being covered with glacial drift.

Sugar Creek Basin.

Sugar creek, like Walnut and Raccoon creeks, heads in the older Paleozoic rocks, east of the accompanying map, and in its southwesterly course cuts successively through the Lower Carboniferous limestones, sandstones, and shales, the Mansfield sandstone, and well into the overlying Coal Measures. Large quantities of the Mansfield sandstone are exposed in north central Parke county and southeastern Fountain county, some of the exposures in this area being thicker than any observed elsewhere in the State.

Sugar Creek below Rockport.—That part of Sugar Creek valley between the Wabash river and the C. & I. C. Railway lies in the productive Coal Measures and was not explored. It is mostly bottom land and there are probably few rock exposures. Along the railway north of Sugar creek, up the Rush Creek valley, are small exposures of black shale, with a little shaly sandstone in places. At and north of Tangier the slopes of Rush creek are covered with glacial drift, and no rock exposures were observed.

Just east of the C. & I. C. Railway on the north bank of Sugar creek is an outcrop of gray and black shale, and about half a mile east of the railway is a small outcrop of soft yellow sandstone somewhat similar in quality to that in the bluffs southwest of Rockport.

Along the bluff in the west and northwest parts of Sec. 35 (17 N., 8 W.), which is a quarter to a half mile west of the creek, there is a heavy bed of yellow sandstone that varies in thickness on the outcrops from twenty to fifty feet. It is exposed in perpendicular and overhanging bluffs in all the little ravines and gullies, but in most places between the small watercourses the rock is concealed by drift material. The stone is underlain by coal, which has been mined for local use at several points. While the sandstone occurs in great quantities along this bluff, it contains too many iron secretions to have more than a local value.*

Along a small winding tributary from the west and north in the north part of Sec. 35 and the west part of Sec. 26 (17 N., 8 W.) the same bed of sandstone is exposed. In several places it is sufficiently uniform for

*The location of this sandstone bluff is shown on the map by broken lines.

good bridge stone or heavy masonry of any kind; in certain localities it contains much iron oxide and iron sulphide. The chalybeate (sulphur) spring comes from the decomposing pyrite in the sandstones and shales. In passing up the ravine the sandstone is succeeded by overlying black shale and shaly sandstone.

Rockport.—There were formerly a mill and several houses at the bridge across Sugar creek in the northeast quarter of Sec. 35 (17 N., 8 W.), and while the mill and most of the houses have disappeared the place still retains its old name, Rockport. There are large exposures of massive sandstone here on both sides of the creek. On the south side of the creek near the mouth of a small tributary from the south, near the site of the old mill, the water has cut a deep, precipitous gorge in the sandstone which is known as the Devil's Den. It is an admirable location for a quarry for rough building stone, owing to the great thickness (thirty to forty feet) of the stone and the little waste material overlying it. In point of durability and ease of working it would be suitable for any kind of work, but the rather dark buff and yellow color will not make it attractive for fine buildings. The natural face is smooth and even, the angles sharp and firm, indicating both homogeneity and durability. Like most of the massive sandstone of this region it is soft in the interior, but hardens on exposure.

No rock has been quarried at the Devil's Den, but a quarry has been opened on the north side of the creek opposite from which probably 2,000 cubic feet or more of stone have been taken. The stone is inferior in quality and in a poorer position for quarrying than that on the south side of the creek. A section of the quarry face shows:

Section of the quarry at Rockport.

	Feet.
Soil	2 to 6
Micaceous sandstone	40
Blue-gray sandy shale	25

The sandstone varies in color from a blue-gray to brown, in places variegated. The upper ten feet of the sandstone are more or less shelly, and it is cross grained in several places. The shale closely resembles that used for manufacturing paving brick.

A quarter of a mile west of the quarry on the north side of the road is a rugged crescent-shaped bluff of the sandstone underlain by coal. A small quantity of sandstone has been quarried at this locality.

The sandstone at Rockport and vicinity is thought to belong to a horizon above that of the Mansfield sandstone. The reasons for so thinking are not conclusive and could only be established by a shaft or boring extending below the bottom of the valley. It is probably the equivalent of the stone at Coxville and at Cannelton.

Between Rockport and Sugar Mill Creek.—Along the north side of Sugar creek above the quarry at Rockport are large exposures of buff and yellow sandstone and black shale. Through Sec. 25 (17 N., 8 W.) the sandstone bluff twenty to thirty feet high is almost continuous and much good homogeneous sandstone is exposed. In a few places the face of the stone is marked with veins, seams, and pockets of iron oxide, but in many places it is smooth, even, seamless, moss-covered, and indicates a good durable stone. The absence of bedding planes in large measure prohibits its local use where it is needed in only small quantities, as it could not be quarried to advantage without the use of channelers and steam drills. However there are a great many massive boulders that have fallen off the parent ledge and lie strewn along the foot of the bluff. The sharp corners and the even surface of these boulders indicate homogeneity and durability, and a good building stone for local use could be easily and cheaply obtained.

Considerable sandstone outcrops through the north part of Sec. 30 (17 N., 7 W.), some of it being more thinly stratified than that above described and containing some intercalary shale. On the east side of Sec. 30 and the west side of Sec. 29 the strata become more diversified. A section of the bluff about half a mile below the mouth of Sugar Mill creek shows:

Section near mouth of Sugar Mill Creek.

	Feet.
Yellow sandstone	5
Black shale	3
Gray and yellow striped sandstone	12 to 15
Shale brown to black containing pockets of coal	12
Cross-bedded sandstone, shale, and coal	12 to 15

The coal near the base is ten to twelve inches thick and dips west four or five degrees.

On the south side of Sugar creek between Rockport and Sugar Mill creek there is very little if any sandstone of economic importance except that along Roaring creek. On Slate Run, Sec. 25 (17 N., 8 W.) and Sec. 31 (17 N , 7 W.) there is an outcrop of black limestone in a bed of black shale. The limestone occurs in two layers which in one exposure shows a thickness of four to six inches each. In another exposure near by, these layers were eight to ten inches thick. Some nice black marble could be obtained here, but it is doubtful if it could be quarried in sufficient quantities to be profitable.

Roaring Creek.—Coal has been mined for local use at several places along Roaring creek; in the southwest quarter of Sec. 29 (17 N., 7 W.), in the southwest quarter of Sec. 32 and the southeast quarter of Sec. 31. The coal is in lenticular masses or pockets and nowhere thick enough to be mined with much profit. It is accompanied with much black shale and gray and yellow sandstone. The sandstone varies from 20 to 40 feet in thickness, and occurs in regularly stratified layers. The bottom part next to the coal and shale in most places contains much pyrite, some conglomerate and false bedding. The upper part is regularly bedded and free from impurities, but frequently contains gray and yellow banded colors Good bridge and foundation stone could be obtained in a number of places along Roaring creek through the south part of Sec. 32 (17 N., 7 W.) and in the tributary ravine in the southeast quarter of Sec. 31 (17 N , 7 W.).

About a quarter of a mile above Roaring creek on the south bank of Sugar creek is an outcrop of typical, false-bedded, massive, Mansfield sandstone, eight to ten feet exposed. There is another similar outcrop about a quarter of a mile below the mouth of Sugar Mill creek on the south side of the creek. In neither place is it sufficiently uniform to have any economic value.

Sugar Mill Creek.—Sugar Mill creek is a large tributary of Sugar creek from the northeast which heads in the Lower Carboniferous rocks in Montgomery county, and cuts through both Lower Carboniferous rocks and the Coal Measures in both Fountain and Parke counties. A glance at the map will show the diversified character of the rocks along its course. Near the mouth is a small outcrop of Lower Carboniferous limestone (St. Louis?) overlain by conglomerate, sandstone (Mansfield), and shale; and a short distance above, about the mouth of Greene creek, the Mansfield sandstone is below the water level and sandstones and shales of more recent age form the bluffs for two miles or more above when the Mansfield sandstone reappears and is followed by Coal Measures, Mansfield sandstone and Lower Carboniferous.

No outcrop of Mansfield sandstone was observed on Greene creek, a large tributary of Sugar Mill creek from the north, but soft sandstone belonging to a horizon above the Mansfield stone has been quarried in small quantities in the northwest quarter of Sec. 8 and the northeast quarter of Sec. 7 (17 N., 7 W.). The quality is not sufficient to merit more than a limited local usage. Coal occurs in several localities.

Along the south side of Sugar Mill creek, east from the mouth of Greene creek, is a precipitous bluff of sandstone and shale with thin seams of coal. In one of the short ravines cutting back into this bluff the coal reaches a thickness of three feet and is mined for local use. The shale here resembles that used for making paving brick. There is considerable sandstone along this bluff which might be used for building stone if it were accessible, but the heavy covering of glacial drift prohibits its use to any great extent.

On the west side of the creek on the northwest quarter of the southeast quarter of Sec. 21 (17 N., 7 W.) is a bold projecting point known as the Pinnacle, which consists of a narrow ridge of the blue-black, brick shale 40 feet in thickness overlain by a narrow ledge of massive sandstone 10 feet thick. The sandstone might have a local value for bridge stone. The shale is in admirable position for cheap mining and may prove valuable if means of transportation are ever provided.

There is a small outcrop of false-bedded Mansfield stone in the creek bed below the iron bridge in the northeast quarter of Sec. 21 (17 N., 7 W.) and about half a mile above the iron bridge near the middle of Sec. 15 (17 N., 7 W.), on the east side of the creek is a small quarry in Mansfield sandstone. It belongs to Mr. Heath and has been worked to some extent for bridge stone; the abutments for the iron bridge a half mile below were obtained here. A section of the quarry face shows:

Section of Mr. Heath's quarry.

	Feet.
Thinly bedded sandstone	4
Massive yellow sandstone grading into drab shale	8
Shale and shaly sandstone	10
Massive gray and brown sandstone	20

North and northwest of Heath's quarry in the northwest quarter of section 15, the southwest quarter of section 10 and the southeast quarter of Sec. 9 (17 N., 7 W.) the Mansfield sandstone outcrops in large quantities, being 75 to 80 feet thick in places. The base of the bluffs consists of gray and yellow sandstone, the upper part is brownstone, which varies in thickness from eight to 25 feet. The colors and texture of the brownstone resemble that at Mansfield, but the structure on the outcrop is not the most promising. In some places it is in thinly stratified layers two or three inches thick, in other places it shows cross grain accompanied by variegated colors. Closer investigation may show some good stone in this locality. Some preliminary work has been done by Hunter and Hollenbach on land leased from Mr. Milligan. One or two drifts were started in the bluff, but only penetrated a few feet, none of them beyond the limits of the thinly laminated stone. There is some good even grained building stone in the gray and yellow stone underlying the red or brownstone, but it could not be quarried in large quantities profitably unless the overlying brownstone should prove valuable enough to be quarried at the same time.

There is considerable shale in and overlying the sandstone in the bluff on the south side of the creek at Russell's old mill in the northeast quarter of Sec. 16 (17 N., 7 W.). A quarter of a mile north of the mill on the east side of the creek the massive gray and buff sandstone outcrops 10 to 20 feet on the banks of the creek and is overlain by 25 to 40 feet of drift.

In the north part of township 17 N., 7 W. in sections 3 and 4 and the north half of sections 9 and 10, no Mansfield sandstone was observed, but there are exposures of sandstone belonging to a higher horizon accompanied by much black shale and some coal. Coal has been mined in the small ravine that heads near Russell Mills postoffice (Grange Corner) and flows west through the north part of Sec. 10 and in the ravine from the northwest in the north part of Sec. 4 (17 N., 7 W.).

In the southwest quarter of Sec. 34 (18 N., 7 W.) and in Sec. 33 along the small ravine from the northwest, ferruginous yellow sandstone and black shale are exposed, but none of economic value was observed.

The best building stone in this part of the valley is at J. R. Switzer's quarry in the northwest quarter of Sec. 34 (18 N., 7 W.), where several thousand cubic feet of stone have been quarried for foundations in Wallace and vicinity. The stone is gray and yellow, in some places slightly variegated. It is micaceous and splits easily with or at right angles to the grain. A section of the quarry face shows:

Section at Switzer's quarry.

	Feet.
Soil	2 to 4
Thin shelly sandstone	2
Massive gray and yellow sandstone	10
Shelly sandstone	3 to 6

In places the stone contains iron pebbles, but the greater part of the bed is free from impurities. In some places it is underlain by black shale which decays more rapidly than the overlying sandstone, thus causing the sandstone to form overhanging ledges. This stone deserves a more extensive local usage than it has had.

On both sides of Sugar Mill creek in the southeast quarter of Sec. 34 (18 N., 7 W.) is a heavy ledge of coarse ferruginous sandstone underlain by black shale. Some bridge stone might be obtained here, but the greater part of it contains too much segregated iron oxide to have any value.

On the north side of the creek nearly opposite the mouth of Wolf creek is a small isolated exposure of yellow sandstone, known locally as the "Snake Den," from which a small quantity of inferior stone has been taken.

On Wolf creek the sandstone outcrops for nearly three-quarters of a mile from the mouth. At the Wolf creek falls, and for nearly a quarter of a mile above, the stone outcrops in the bed of the creek and in the bluffs on each side, but contains too much iron pyrites and iron oxide to have any commercial value. Near the upper limit of sandstone on Wolf creek in Sec. 2 (17 N., 7 W.) the stone contains less iron than at the falls, is more regularly bedded, and contains much intercalary shale. While there is some good building stone, but little of it is accessible on account of the shale and overlying drift.

Between the mouth of Wolf creek and the Narrows of Sugar Mill creek but very little sandstone is exposed and the little that is has no commercial value.

In a small ravine south of the wagon-road in the southwest quarter of Sec. 25 (18 N., 7 W.), red, yellow, gray, and blue, variegated sandstone has been quarried in small quantities. The record of a drilled well on the north side of the road in the same quarter section gives:

	Feet.
Blue and drab shale ("Soapstone")	35
Variegated red, yellow, and gray sandstone	$66\frac{2}{3}$

The Narrows on Sugar Mill creek are in the east side of Sec. 25 and the west side of Sec. 26 (18 N., 7 W.) where for about a half mile the creek has cut a narrow channel into the massive sandstone which forms the bottom and sides of the channel. The smooth rock bottom and the regular perpendicular walls resemble an artificial waterway. The stone has a pinkish red color for the most part, but varies to buff and gray in a few places. In many places the stone is cross-grained as shown by a faint banding of colors, but it weathers evenly with a smooth surface and is not ridged as it is in many localities where it is cross-grained. On the east side of the creek near the lower end of the Narrows and also near the upper end a small watercourse has cut a deep channel back for some yards from the main creek exposing some nice sandstone.

While the variegation in color and the patches of cross-grain injure much of this stone, there is a great deal of good building stone and much of it suited for heavy masonry. It would require a closer investigation and some preliminary work to determine whether it could be quarried in large quantities with profit, even if transportation facilities were at hand, which is not the case at present.

On the west side of the creek, nearly a quarter of a mile above the Narrows, is a sandstone quarry where several thousand feet of stone have been extracted. A section of the quarry face shows:

Section of Sandstone quarry near the Narrows.

	Feet.
Sand	2
Boulder clay	3
Massive yellow sandstone	12

The sandstone is micaceous and contains numerous seams, many of which are no doubt powder cracks. The stone is inferior in quality to much of that in the Narrows.

No sandstone was observed along Sugar Mill creek above the quarry just described. The valley above Wallace was not traversed, but citizens report that there are no rock outcrops above that village. A drilled well in Wallace is said to have struck rock at a depth of 66 feet. Less than a quarter of a mile west of Wallace, on the north side of the wagon road, is a magnificent chalybeate spring which emerges from a slope of glacial drift.

Turkey Run and vicinity.—Along Sugar creek between the mouth of Sugar Mill creek and Turkey run sandstone outcrops in a number of places, but it is of inferior quality for building purposes. Through the south part of Sec. 28 (17 N., 7 W.) are some bold bluffs of Mansfield sandstone, which contains much iron oxide and false bedding.

Turkey run has cut a narrow, winding channel through the Mansfield sandstone 40 to 60 feet deep with nearly perpendicular and, in places, overhanging bluffs on either side. The stone is yellow and gray in color and contains numerous streaks and patches of iron oxide. While stone for heavy masonry might be obtained here, it is doubtful if first-class building stone could be obtained in paying quantities. The same is true of the stone along Sugar creek between Turkey run and Rock Hollow in a less degree, as in some places along the north side of the creek there are patches of considerable extent which appear to be free from the iron blotches. Mr. Hooghkerk reports that in drilling the well at the Turkey run hotel the drill passed through:

Well section at Turkey Run.

	Feet.
Gravel and sand	31
Sandstone (Mansfield)	30
Limestone	2
Sandstone, white, fine-grained (Riverside)	30
Total	93

The limestone is supposed to be Lower Carboniferous and the sandstone overlying it the Mansfield sandstone.

The sandstone in the vicinity of Turkey run has been deeply scored by the glacier, the sand that has been scraped off being distributed over the region to the south. Glacial striæ bearing south, 37 degrees east, are clearly shown in two places: one about a quarter mile east of the hotel, the other more than a half mile east. This glacial action has scraped off all the disintegrated material from the top of the sandstone, if any such ever existed, and the fine state of preservation of the striæ shows that there has been no disintegration of the stone at these points since that date, probably several thousand years ago, surely a strong proof of the durability of the stone.

Rocky Hollow.—Rocky Hollow, which lies mostly in the northwest quarter of Sec. 27 (17 N., 7. W.), is a deep narrow gorge cut into the massive Mansfield sandstone. The walls are so high and precipitous that the gorge can be entered only at the mouth and at the head of a few of the terminal ravines, many of which are cut down so abruptly at the terminus as to be practically inaccessible. No part of the gorge can be traversed except in time of low water. While much of the stone along the bluffs is cross-bedded and ferruginous, in a number of places it is free from imperfections and would furnish good buff and gray building stone, should it ever be made accessible to transportation. This deep winding rocky gorge, with its precipitous overhanging moss-grown walls, is a romantic spot and attracts a great many tourists during the summer months.

On the south side of Sugar creek, opposite and above the mouth of Rocky Hollow, large quantities of buff and gray sandstone are exposed, some of which is good building stone. A promising exposure is that in the small ravine on the south side of the creek about a quarter of a mile or a little more below the bridge at the Narrows, where there is a thickness of ten feet of flagstone on the top, underlain by 30 feet or more of massive gray sandstone. Southeast from the above ravine, about 200 yards, the flagstone increases in thickness to 15 feet or more.

Flagstone quarry.—Mr. W. B. Hooghkerk opened a flagstone quarry here in 1880 and operated it for three years. Most of the product was used for flag and curb stone in Rockville, this county, and about Tuscaloosa, Ill. Probably 20,000 cubic feet or more were taken out of this quarry. The opening is about 100 feet long, 12 feet deep and quarried back 20 to 30 feet into the bluff. The stone lies in quite regular layers one to six inches thick, the upper layers being thinner than the bottom ones. The layers are in many places separated by thin films of clay or shale, which makes a separation of the flags an easy matter. The stone is not as durable as much of the Mansfield sandstone, owing to the abundance of mica and carbonaceous matter, yet the flags that have been lying in the quarry for 12 years or more show little signs of decay. If the stone was properly quarried and seasoned it would no doubt prove as durable as much of the stone in general use.

East from the quarry the flagstone grades into black shale, which outcrops in great quantities in the ravine between the quarry and the Narrows.

The Narrows of Sugar Creek.—At the Narrows in the northwest quarter of Sec. 26 and the northeast quarter of Sec. 27 (17 N., 7 W.) Sugar creek has cut a narrow channel through the Mansfield sandstone for about a quarter of a mile. The channel is twenty to thirty feet deep and sixty to one hundred feet across. The prevailing color is gray with patches of yellow. The bluffs contain many irregular hollows and rounded prominences, showing lack of homogeneity. The hard, indurated surface and the bold cliffs which have long been exposed to the rapid currents of Sugar creek rushing through this narrow channel show the stone to be very durable, and to resist abrasion much better than one would expect from its friable nature. It would make a good bridge stone, but is not sufficiently homogeneous in either color or texture for good dimension stone. The bridge across Sugar creek is placed on the natural rock abutments.

A hundred yards or more below the bridge a thinly bedded sandstone overlies the massive sandstone. Above the bridge the massive sandstone extends only a few hundred yards, where it is replaced by the overlying shale, thin-bedded sandstone, coal, and fire clay. The black shale occurs in a bed fifty to eighty feet thick for more than a mile above the Narrows on the main Sugar creek and on Brush creek tributary from the north, and the Fullwater branch from the southeast. It contains intercalary sandstone, coal and fire-clay, the coal in some places reaching a thickness of 12 inches.

The lower course of *Brush creek* is mainly in black and drab-colored shale, which contains some sandstone and sandy layers. The middle course is mainly through drift-covered slopes with no rock exposures. The upper part of the creek was not examined, but is said to contain some shelly sandstone of no commercial importance.

The bluffs on the lower part of *Fullwater branch* for half a mile or more from Sugar creek are mostly black shale, with some coal and fire-clay. In the east side of the southeast quarter of Sec. 26 (17 N., 7 W.) the shale is in part replaced by heavy bedded sandstone. The sandstone occurs as a lenticular mass in the shale bed. It has a maximum thickness of twenty feet, is evenly bedded, somewhat micaceous, comparatively homogeneous and durable. Great massive boulders of it have tumbled into the watercourse and almost obstructed the channel. It is underlain by a thin streak of cannel coal, gray shale, and shaly sandstone. Good stone for local use could be obtained from these large boulders and exposed ledges at this locality, but the thickness of the overlying shale and drift prevent its being quarried in large quantities.

Near the upper limit of the sandstone ledge is an outcrop of black limestone three to five feet thick, in layers 10 to 20 inches thick. It occurs in the black shale, with shale both above and below it. Fine black marble might be obtained from this limestone, but it is doubtful if it could be economically quarried in large quantities.

Sugar Creek, between Keller Branch and the Shades of Death.—On the lower course of Keller branch and along Sugar creek for half a mile or more, the black shale outcrops in large quantities, underlain in places by false-bedded ferruginous sandstone. The black shale outcrops for a half mile above Keller branch where it is replaced by the Mansfield sandstone which, beginning in the northeast quarter of Sec. 24 (17 N., 7 W.), forms almost continuous bluffs on one or both sides of Sugar creek up to the Shades of Death in Sec. 11 (17 N., 6 W.), in some places at the bottom of the valley, in others near the tops of the hills.

In the southeast quarter of Sec. 13 (17 N., 7 W.) and extending into the southwest quarter of Sec. 18 (17 N., 6 W.) is a bold cliff of massive Mansfield sandstone, which is one of the thickest deposits of this stone in the State. At the sulphur spring north of Mr. Durham's house the outcrop measures 80 feet in thickness (Barometer), and a quarter of a mile northeast it measures 100 feet. In both places the stone extends below the bottom of the creek, and there are no wells nor borings to show its depth. The glacier has scraped the top of it, no telling how much, so that 80 or 100 feet marks only part of the present thickness, and a smaller part of the original thickness. Unfortunately the quality is not equal to the quantity, as it contains some false bedding and patches of segregated iron oxide with much iron pyrites near the base. However, there is much good durable building stone well adapted to heavy masonry, and no doubt much gray and buff building stone of good quality could be obtained here Whether it could be profitably quarried in large quantities would require closer investigation. Near the base of this bluff, in the vicinity of Mr. Durham's sulphur spring, there is considerable conglomerate made up of white quartz pebbles about the size of a pea, in a matrix of yellow and gray sandstone. It varies in thickness from 2 to 20 feet. In places it is banded—layers of pebbles separated by layers of sand.

Two prominent remnants of the deep erosion in this sandstone stand on the north side of the creek opposite this high bluff, and consist of table rocks, one about 20 feet and the other 50 or 60 feet high. They have abrupt faces on the creek side, and steep but less abrupt slopes on the opposite side. The stone is too cross-grained and ferruginous to have any value.

There is evidence that in a former stage of its history Sugar creek was one-quarter to one-half mile south of these bluffs, and ran close to the southwest corner of Sec. 18 (17 N., 6 W.). East of this former channel in the northwest quarter of Sec. 19, and the S. W. quarter of Sec 18 (17 N., 6 W.) the massive Mansfield sandstone outcrops over an area of several acres. In one place on the roadside in the N. W. quarter of Sec. 19, it shows glacial striæ running south 45 degrees west. A well drilled near the middle of the N. W. quarter of Sec. 19 is said to have passed through soil and drift 27 feet, and penetrated 46 feet into the yellow sandstone.

In the small tributary from the southeast in the south part of Sec. 18, and extending into sections 19 and 20, are extensive outcrops of shelly, and cross bedded, yellow sandstone. Where the wagon road crosses the branch in the southwest quarter of Sec. 18 (17 N., 6 W.) there are large quantities of black shale, which grades into sandstone both up and down the branch from this point.

On Sugar creek, a short distance above the mouth of the tributary mentioned, near the middle of Sec. 18 (17 N., 6 W.), the Lower Carboniferous limestone appears in the bottom of the valley and rapidly rises on the hillside in ascending the creek, within a half mile, reaching a height of 60 or 70 feet above the bottom of the valley. Most of the limestone has a blue-gray color, but in some places it is reddish-brown. Certain layers are highly fossiliferous. In a small ravine on the east side of the creek, about 100 yards east of the wagon road, near the northeast corner of Sec. 18 (17 N., 6 W.) is a nearly perpendicular bluff of limestone and drab-colored shaly sandstone. The limestone immediately overlying the fine-grained sandstone, contains great numbers of geodes, consisting of an opalized quartz crust lined with white and limpid quartz crystals.

On the west side of the creek, in the southeast quarter of Sec 7 (17 N., 6 W.), about a quarter of a mile below the new iron bridge, a small watercourse has cut a channel back 100 yards or more from the creek, forming a deep and picturesque ravine. A section in this gorge shows the following strata:

Section on Sugar Creek, southeast quarter of Sec. 7 (17 N., 6 W.).

	Feet.
Massive Mansfield sandstone	40
Hard calcareous shale	10
Shelly limestone, fossiliferous	25
Geodic limestone	15
Shelly limestone	10
Blue-gray shaly sandstone	5

The limestone decays more rapidly than the Mansfield stone, and thus undermines the latter, until by its own weight the overhanging mass breaks off, tumbling in immense boulders into the ravine and leaving a smooth, perpendicular face. Over this perpendicular face the water rushes in time of a freshet, forming a cascade 50 feet or more in height. While good building stone occurs in these picturesque bluffs it is inaccessible.

The accompanying figure (Fig. 3) shows at the left a section across this gorge a short distance below the waterfall. The right side of the figure is a section of the bluff on the north side of Sugar creek about 200 yards above the falls.

Fig. 3. Section on Sugar creek, northeast corner of Parke county, Ind.

b—Lower Carboniferous limestone.
c—Massive Mansfield sandstone.
f—Glacial drift.

On Sugar creek, less than a quarter of a mile above this waterfall, the limestone horizon is beneath the creek level, and the Mansfield sandstone again forms the bottom of the valley. This disappearance of the limestone is not due to a sharp dip in the strata, but to the erosion of the limestone before the sandstone was deposited upon it.

At the iron bridge in the southwest quarter of Sec. 8 (17 N., 6 W.) the sandstone has been quarried in small quantities on each side of the creek, and also a hundred yards above the bridge on the north side. The stone is well suited for bridges and foundations, being strong, durable and easily wrought.

Large quantities of sandstone and shale are exposed in the ravine from the southeast just above the bridge, but the sandstone is of inferior quality.

Above the bridge, on the north side of the creek, through Sec. 8 (17 N., 6 W.), heavy ledges of evenly bedded, smooth faced sandstone occur in the bluffs. In some places it contains patches of conglomerate, consisting of small quartz pebbles, yet in most places this stone would furnish a good building and bridge stone. Through the middle of Sec. 8 the Lower Carboniferous limestone is exposed at the base of the bluffs for a quarter of a mile or more, and sinks below the bottom of the valley just below the mouth of the ravine from the east, in the northeast quarter of Sec. 8. It almost immediately reappears and the outcrop is then almost continuous at varying heights along the bluffs up to and beyond the Shades of Death, while the Mansfield sandstone and accompanying shale and conglomerate in a bed of variable thickness form the upper part of the bluffs, overlain in most places by more or less glacial drift. Building stone of good quality occurs at different places along this part of the creek in sections 5, 4, and 3 (17 N., 6 W.). The outcrop on the hill northeast of the mill in the southeast quarter of Sec. 5 (17 N., 6 W.) shows forty feet of Lower Carboniferous, drab-colored, shaly sandstone at the base, with two intercalated beds of limestone two to four feet thick, and overlain by twenty-five feet of massive Mansfield sandstone.

Shades of Death.—The picturesque summer resort known as the Shades of Death, in the northwest quarter of Sec. 11 (17 N., 6 W.), is very near the upper (eastern) limit of the Mansfield sandstone horizon in the Sugar creek basin. A section of the strata from the hotel to the creek, based on barometric measurements, shows:

Section at the Shades of Death.

	Feet.
Glacial drift	50
Massive yellow Mansfield sandstone	40
Lower Carboniferous shaly sandstone and limestone	80
Total	170

The prevailing color of the Mansfield sandstone is yellow to yellow-brown, being variegated with lighter and darker streaks in many places. It has a coarse-grained, open, porous texture, with considerable segregated iron oxide in many places, and much pyrite near the base.

Emerging near the base of the Mansfield sandstone in the ravine at the hotel, there are several chalybeate springs, the water from which forms a beautiful little cataract over the Lower Carboniferous rocks below the springs.

The Mansfield sandstone occurs in a massive bed 40 feet thick in this ravine above the falls, but contains much segregated iron oxide and false bedding. At the high bluff on the cliff overlooking Sugar creek it occurs as a fine conglomerate, the separate pebbles being about the size of wheat grains. It is quite durable, but the cross grain would interfere with working it, and the variegated color would spoil its value for building stone.

On the north side of Sugar creek, opposite the Shades of Death, the sandstone occurs in as heavy a deposit as on the south side, but the slopes are more retreating, and in many places the sandstone is covered with soil and drift. Stone for local use may be obtained in this locality, but the outcrops do not suggest a desirable dimension stone where uniformity of color and texture are required.

The Lower Carboniferous, drab-colored sandstone (Riverside) here is quite shelly on the surface, but in the interior is more or less massive as evidenced by the fresher exposures on the overhanging creek bluffs. It forms bold massive cliffs on Indian creek in sections 7 and 12 (17 N., 6 W.). The cliff at "Devil's Backbone," at the mouth of Indian creek, is 100 feet high (barometer), all of this being drab-colored sandstone. In many places this rock contains iron pyrites in considerable quantity, and is more or less shelly on all the exposures observed. Closer investigation might show areas of fairly good building stone in this formation, but it will in no place be as durable as the Mansfield stone. It contains two or more layers of limestone, varying from a few inches to six or eight feet in thickness.

The valley was not explored above Indian creek, and if the irregularities between the Lower and Upper Carboniferous formations are as great as they are down the creek there may be isolated exposures of the Mansfield sandstone above this point. None were reported.

Coal Creek Basin.

The Mansfield sandstone outcrops on all the large tributaries of Coal creek, viz , East fork, Dry run, Turkey run, and North fork, the largest and best exposures being on the East fork, but even there it is inferior in quality to stone both north and south of this valley.

The part of Coal creek below Veedersburg was not explored, as it runs through the productive Coal Measures. Sandstone is reported in several places, but none of any value for building purposes.

East Fork of Coal Creek.—The only outcrop of Mansfield sandstone on Coal creek below its confluence with the East fork is in the north part of Sec. 13 (19 N., 8 W.), a mile southwest of Veedersburg at the wagon bridge below the mill, where it is exposed in the bottom of the creek. It contains too much iron pyrites and false bedding to have any economic value, even if it were above the water-level.

There are some large beds of shale on the East fork of Coal creek in Secs. 8, 17, 15, and 16 (19 N., 7 W.). The largest bluff is on the north side of the creek in the northwest quarter of Sec. 17 (19 N., 7 W.), where there is an almost vertical bluff of 35 to 40 feet of shale overlain by 10 or 12 feet of gravel.*

The first outcrop of the Mansfield sandstone observed in ascending the East fork of Coal creek is in the east side of Sec. 17 (19 N., 7 W.) at the bridge below the old mill, where it is exposed in the bottom of the creek and in the creek bank, is very false bedded and pyritiferous, overlain by a more evenly bedded coarse-grained, buff to bluish drab-colored sandstone, with intercalary shale. This overlying sandstone has been quarried to considerable extent on the north side of the road at the mill on the property of Mr. Frank Coates. During the past five years there has been more than 40,000 cubic feet of stone taken out of this quarry. It has had a local use for many years, the foundation of the mill having been taken from it sixty years ago. The separate layers of the stone vary from one inch to 30 inches in thickness, the upper layers being thinnest. In the interior of the bed, as shown in the bottom of the quarry, the rock has a blue gray color, which weathers to a yellow gray as shown at the top of the quarry. The stone will probably never have more than a local use

There are other small sandstone quarries on the south side of the creek a quarter of a mile west of the mill, where the stone occurs in heavier layers than at the mill, but the layers are not continuous, grading rapidly into shale. The intercalary sha'e at both places contains much iron pyrites, which on the weathered surface in places stains both the shale and the sandstone a yellow and yellow-brown color.

---

* For particulars on the shale deposits, see the accompanying report on the clays and shales by the State Geologist.

Near the middle of the east side of section 16 (19 N., 7 W.) is another small exposure of the Mansfield sandstone in the creek. There are larger exposures on Clifty creek, a small tributary from the south, in the west part of section 15 (19 N., 7 W.). Near the upper (south) limit of the sandstone on Clifty it weathers into thin, shaly layers, north of which it occurs in a massive bed, ten feet exposed, weathering very irregularly.

At the confluence of Clifty creek with the East Fork, there is an unconformity in the strata, shown by the black and drab shale resting against the sandstone and conglomerate with discordance in bedding.

There is a fine exposure of the dove-colored shale at this point, but the sandstone has no economic value. A few layers near the base of the cliff contain some good stone, but are overlain by too much waste material to have any commercial value.

In the southwest quarter of section 10 (19 N., 7 W.) are bold bluffs of sandstone 30 to 40 feet high and variegated in color, being dark brown and yellow to yellow-brown. There is some nice looking brownstone in the bluff on the south side of the creek, but it is overlain by a great quantity of loose, shaly material, so that it is practically inaccessible.

The sandstone outcrops in a small ravine on each side of the Veedersburg-Hillsboro road in the northeast quarter of section 10 (19 N., 7 W.), but has not been used.

There has been a small quantity of imperfect sandstone quarried on the south side of the wagon road in the northwest quarter of section 11 (19 N., 7 W.). The stone is brown with many gray patches and numerous iron secretions.

The outcrop of sandstone is almost continuous on both sides of the creek from the middle of Sec. 11 (19 N., 7 W.) up to and beyond Hillsboro, near the middle of section 12. It has heen quarried on both sides of the creek. On the north side of the road, one-fourth mile west of Hillsboro, a section of the quarry face shows:

Section west of Hillsboro.

	Feet.
Soil	1
Shale	3
Shelly sandstone	3 to 10
Yellow-gray sandstone	12

There has been probably 8,000 cubic feet of stone taken from the lower yellow-gray sandstone.

On the south side of the creek the stone has been quarried on the face of the bluff for 200 yards or more through the west side of section 12 and the east side of section 11 (19 N., 7 W.), about half a mile west of Hillsboro, where the stone is quite variegated in color, much of it being either yellow or light gray, and containing patches of bright red and brown. It is overlain by a heavy bed of drift, so that the quarries are confined to within a few feet of the face of the bluff.

The largest quarries at *Hillsboro*, in fact the largest in the Coal Creek basin, are south and southeast of the town, and lie along a small tributary from the southeast, which joins the main creek close to the middle of Sec. 12 (19 N., 7 W), the quarries extending for a quarter of a mile above the confluence. There are a number of quarries along this branch which have been worked at different times, 100,000 cubic feet or more in all having been removed They were formerly owned by Mr. L. K. Stevens, but were sold to different parties. Mr. Wineberg, Mr. Connell and Mr. N. R. Harlan took out stone at different places. Mr. Clarence W. Moore, of Chicago, Ill., now (July, 1895) is said to own the quarry on the west side of the branch, nearest the town. The others belong to the Hillsboro Brownstone Company.*

Considerable stone has been shipped from Hillsboro and from the present appearance of the openings much good stone has been obtained, but it must have been at considerable expense, owing to the amount of waste material to be handled. Besides the glacial drift overlying the sandstone there are shaly and shelly patches of worthless stone diffused through the bed, and occasionally patches of segregated iron oxide, or "iron blisters." The patches of shale and shelly stone in the body of sandstone are a more uncertain quantity than the overlying glacial drift and soil, as they are liable to occur at any time and at any place in the body of the stone. In the lower quarry, the one nearest the town, the stone is largely brownstone, but red, gray and yellow patches occur merging into one another. Where the greatest proportion of the stone is brown there the most iron kidneys occur. This opening is about 75 yards long and has been quarried back 20 or 25 feet into the bluff.

At the brickyard on the east side of the branch opposite the quarry above mentioned, the stone has been quarried a very little, and so far as exposed it is very shelly and broken. Eighty yards southeast of the brickyard on the east side of the branch some good brownstone is exposed, but it is overlain by 20 to 30 feet of shale, iron ore, fire-clay, and shelly sandstone. A well back from the face of this bluff is said to be through 20 feet of drift and loose rock to the sandstone, and to have penetrated 17 feet into the brownstone. About a quarter of a mile above (southeast of) the brickyard, on the east side of the branch, there is an exposure of four feet of handsome brownstone at the bottom of the quarry, and Mr. Harlan reports that they drilled through six feet more of the same color, thus making at least 10 feet of brownstone at this point. While it is the most uniform and best appearing stone in any of the quarries, it is unfortunately overlain by 20 feet or more of waste material

*The historical information was furnished by Mr. Nathan R. Harlan, Hillsboro, Indiana.

Along the west side of the branch above the brickyard, the stone is more variegated in color, considerable yellow and buff-colored stone occurring, and in one opening the stone is tinged with pink, approaching the color of a peach blossom. About 150 yards above the upper quarry opening is an outcrop of good yellow sandstone, four feet thick, with very little stripping.

The sandstone extends up this ravine for more than a mile, to near the middle of the east side of Sec. 13 (19 N., 7 W.), but above the quarry openings mentioned it has little or no economic value, being mostly shelly and containing streaks of shale. In the southeast of the northeast of Sec. 13 (19 N., 7 W.), is an outcrop of shale conglomerate, which is near the upper limit of the sandstone in this ravine.

Along the small ravine that flows through Hillsboro sandstone outcrops at various points from the mouth to north of the railroad in the southeast quarter of Sec. 1 (19 N., 7 W.), but none that promises to be of more than local value.

While there is much stone and much good stone in the vicinity of Hillsboro, it is unfortunately overlain by a considerable thickness of glacial drift and shelly sandstone, besides considerable waste material in the bed, such as patches of shale and stone with seams, so that it can not be worked with profit unless the overlying materials can be, in part at least, utilized at the same time. The Hillsboro Brownstone Company has attempted this by making pressed brick out of the overlying clay While handsome brick are obtained, unfortunately the stone at this point is of inferior quality.

The sandstone outcrops in a number of places for two miles or more above (east of) Hillsboro along the bluffs of Coal creek. Where the road on the range line between Sec. 7 (19 N., 6 W.) and Sec. 12 (19 N., 7 W.) crosses the creek the sandstone outcrops on each side of the creek on both sides of the road About fifty yards east of the road on the north side of the creek the sandstone, which is light gray in color and of inferior quality, has been quarried to a slight extent. That on the west side of the road is not so shelly nor so cross-grained, and does not have so many seams. East of the road on the south side of the creek the stone is more shelly than on the north side; but up the creek about 150 yards from the bridge, at Daniel Pickering's quarry, there are 12 to 15 feet of evenly bedded gray sandstone in layers 10 to 30 inches thick, which splits and works nicely and makes a good building stone. The upper part of the bed is a conglomerate made up of white quartz pebbles and is overlain by shale and sand. About 200 yards west of the road on the south side of the creek, just below the mouth of a small ravine from the southeast, is another quarry opening larger than either of the above, in which the stone is light gray with yellow spots and streaks and is overlain by shale and sandstone. It has been quarried for 100 yards or more along the bluff 8 to 10 feet deep and 15 to 20 feet back into the bluff where the stripping becomes too heavy to permit further work with profit.

On the east side of Sec. 7 and the northwest quarter of Sec. 8 (19 N., 6 W.) along a small ravine from east of north, considerable brownstone is exposed. This stone has a beautiful purple and brown color and good texture, but is structurally very imperfect, being thin bedded to shaly on all the exposures. If it could be obtained free from the numerous bedding seams it would make a splendid building stone. If these seams are due wholly to weathering they may disappear back from the surface of the bluff, and if so, the stone might be quarried where the drift material is not too heavy; if, however, the seams are due wholly to the character of the deposition they will extend throughout the bed. This could be determined in large measure by the diamond core drill at no great expense.

In the southwest quarter of Sec. 8 (19 N., 6 W.) on the south side of the creek, the brownstone is heavier bedded, in layers two to ten feet thick, and contains some cross-bedding and patches of shale. The most serious drawback at this point is the large quantity of glacial drift overlying, which is six to ten feet thick on the face of the bluff and thicker back from the bluff.

In the southeast quarter of the southwest quarter of Sec. 8 (19 N., 6 W.), at Jesse Brant's, the sandstone has a light gray color, medium fine grain, and can be dressed easily to a smooth even surface. It has been quarried for local use in bridges, foundations, etc., for 25 years, probably 10,000 cubic feet in all. All the loose stone has been planed off by the glacier, the upper surface of the stone being level and marked by glacial striæ running south 20° west. The same phenomenon was observed in Mr. Brant's well, 100 yards or so back from the bluff, which is 95 feet deep, passes through 12 feet of drift and penetrates 83 feet into sandstone. A well on the south side of the creek at this point 90 feet deep passes through 12 feet of drift and penetrates 78 feet into the gray and red sandstone, the bottom being red.

There is no sandstone of any economic value on this branch of Coal creek above the section line on the south side of Sec. 8 (19 N., 6 W.). There are a few exposures of shelly sandstone and shale as far as Cold Spring mill in the west part of Sec. 16 (19 N., 6 W.). The underlying Lower Carboniferous limestone outcrops on Hannah's Fork in the northeast quarter of Sec. 17 and the southeast quarter of Sec. 8 (19 N., 6 W.), where it is very fossiliferous.

Dry Run, tributary of Coal creek.—No sandstone of any value outcrops on Coal creek between the mouth of the East Fork and the mouth of

Dry Run. Small quantities occur associated with the shale beds at the brick works south of Veedersburg.*

There is only one outcrop of sandstone on Dry run, and that is southeast of Mr. Voorhees' house, at the schoolhouse in the northwest quarter of Sec. 33 (20 N., 7 W.). This stone has been quarried for local use on the north side of the creek, near the schoolhouse, where there is about 20 feet of sandstone exposed, light gray, with yellow and brown streaks, brownish-yellow and some red-brown in color. The bottom of the bed is thinly stratified, while in the upper part of the quarry it is massive and is overlain by sand and gravel. The stone outcrops for 100 yards or more, north of the quarry, along the small ravine from the north, and for nearly a quarter of a mile both up and down the creek from the quarry.

The valley and slopes of Dry run, both above and below this exposure, are covered with a variable thickness of glacial drift. A well in the south part of the northeast quarter of Sec. 28 (20 N., 7 W.) went through 100 feet of drift and penetrated 65 feet into the sandstone without passing through it.

Coal Creek above Dry Run.—Between the mouth of Dry run and Stone Bluff there are several outcrops of shale and coal. About one mile north of Veedersburg and west of the C. & I. C. Railway, on a small tributary of Coal creek from the west, in Sec. 31 (20 N., 7 W.) the shale has been quarried for use in the brick works at Veedersburg and coal has been mined at the same place.

In the southwest quarter of Sec. 19 (20 N., 7 W.) on the west side of the creek are large exposures of black shale associated with some coal, and in places containing a great many fossil coal plants, *sigillaria*, *calamites*, and fern leaves. Coal was at one time shipped from here and is now quarried to some extent for local use; the bed varies from 18 to 30 inches thick. About 200 yards southwest of the coal bank is a small outcrop of massive yellow sandstone in a small ravine from the west, which has been quarried a little for local use.

Stone has been quarried on Mr. Remster's place in the southwest quarter of Sec. 29 (20 N., 7 W.), just east of the Veedersburg-Attica road. The stone occurs in layers two to 12 inches thick and has been quarried to a depth of three feet. It is micaceous, evenly bedded, with thin streaks of blue shale between the layers.

The sandstone outcrops on both sides of the wagon road in the west side of Sec. 20 and the east side of Sec. 19 (20 N., 7 W.). West of the road the stone is exposed 15 to 20 feet, is of a light gray color, massive and has some false bedding.

---

*See the report of the State Geologist for description of the shale and clay deposits of this vicinity.

At the grist mill at Stone Bluff there is an outcrop of 12 to 15 feet of thinly stratified, medium grained white and yellow sandstone underlain by a blue shale. A similar stone is exposed in the creek above the mill. At the mill-dam and extending below it to where the wagon road crosses the creek is an outcrop of the Mansfield sandstone, yellow and gray, coarse-grained, false bedded, and overlain by fire-clay and thinly stratified sandstone. In a small ravine from north of west below the mill-dam the sandstone is exposed and contains a lenticular mass of blue drab shale.

About a mile north of Stone Bluff, along the railroad at the section line on the north side of Sec. 18 (20 N., 7 W.), is a small outcrop of massive yellow sandstone that was quarried for use in the abutments of the bridge at Stone Bluff.

Nearly two miles northeast of Stone Bluff, at the middle of the west half of Sec. 8 (20 N., 7 W.), sandstone has been quarried for use in bridges and foundations. The stone here is yellow-brown and light gray, the yellow predominating, and contains numerous mica scales in places. Over an area of several acres the stone has a very light covering of drift, and well sections show the rock to be of considerable thickness. A well near the quarry shows:

	Feet.
Soil and drift	7
Sandstone	60

A well a quarter of a mile west of the quarry shows:

	Feet.
Soil and drift	4
Sandstone	38

A well a half mile southwest of the quarry shows:

	Feet.
Soil and drift	5
Sandstone and shale	75
"Hard rock" (quartz conglomerate?)	5
Fire-clay	16
Sandstone	3

There is evidently an amount of from 50 to 70 feet of sandstone in this locality, and should it all or a large part of it prove suitable for building purposes it might prove to be a valuable deposit, as it is only three-quarters of a mile from the railroad; in fact the stone extends to the railroad, to the quarry mentioned above. The stripping is not heavy, being only four, five and seven feet in the well sections. A few cores taken out over the area would indicate in a general way the character of the stone through the bed. It is from surface indications one of the most promising localities in the Coal creek basin.

Soft yellow sandstone outcrops along Coal creek in the southwest quarter of Sec. 4, and along the west side of Sec. 10 (20 N., 7 W.), but it has no economic value.

On Turkey run a soft yellow sandstone outcrops in Secs. 8, 9, and 16 (20 N., 7 W.), but it has no economic value. In the northeast quarter of Sec. 16 is an outcrop of arenaceous shale, and near the half mile line on the east side of Sec. 16 (20 N., 7 W) is an outcrop of Lower Carboniferous (Riverside) sandstone and shale.

Southeast Side of the Wabash River Above Coal Creek.

On the east or south side of the Wabash river, above the mouth of Coal creek, there is a great deal of sandstone, exposed both Carboniferous and Lower Carboniferous. Extending to a few miles above Covington, the stone belongs to the Middle Coal Measures; from that point to a short distance above Attica, the base of the Coal Measures, or the Mansfield sandstone predominates, and thence to and beyond the eastern border of the map sheet the Lower Carboniferous (Riverside) sandstone and shale occur. Good building stone occurs and has been quarried in each of these three formations.

Cayuga Pressed Brick and Coal Mining Company's Quarry.—About three miles northeast of Cayuga on the east side of the Wabash river in the southwest quarter of Sec. 27 (18 N., 9 W.), is a large sandstone quarry belonging to the Cayuga Pressed Brick and Coal Mining Company. The quarry was opened in 1888 and continued in operation until the fall of 1892, during which time between 3,000 and 4,000 carloads of stone were shipped to Terre Haute, Ind , Chicago and Danville, Ill., and local points.* No stone has been quarried since 1892.

The stone belongs in the Coal Measures at a horizon above that of the Mansfield sandstone, and on the quarry face has an exposure of 35 to 40 feet of stone, overlain by 15 to 20 feet of gravel, the base being concealed. The upper four to six feet of the stone is very shelly and contains patches of shale. There are irregular streaks of shale and cross-grain structure scattered through the bed, the shale being most abundant at the south end of the quarry. There is much iron pyrites in places sufficient to give a yellow color to the stone, and many iron kidneys in places along the bedding. There is one hard calcareous layer in places near the north end of the quarry, but it is not continuous. The stone is micaceous throughout and has a blue-gray color, due in part to the diffused pyrites and in part to carbonaceous material. The present quarry face shows seven channel cuts with possibly one other concealed by the debris in the quarry The 15 to 20 feet of gravel, which overlies the

*Information by Mr. Decker.

sandstone, is excellent ballast, and the company is now engaged in shipping it for that purpose, which will thus uncover an area of fresh stone. It is doubtful, however, if the stone can be quarried with profit after the gravel is removed, owing to the large quantity of waste rock in the body of the stone, and the lack of durability in the stone itself. The abundance of iron pyrites and the shaly streaks are objectionable features to its use for building stone.

Coal has been mined along the river bluff south of the quarry, and a new mine has recently been opened east of the quarry and west of the old canal bed. Heavy beds of shale are exposed along the river bluff between the quarry and the railroad bridge. Near the east end of the railroad bridge is an extensive gravel deposit, from which large quantities of gravel have been shipped.

Beard, Platt & Kimbrell's Quarry.—On the east side of the Wabash river, in a small ravine from the east, and one and one-half miles above Perrysville, in 19 N., 9 W., the south part of section 23, Beard, Platt & Kimbrell, of Danville, Ill., have opened a sandstone quarry, but have not shipped any stone. A section of the bluff shows:

Section Northeast of Perrysville.

	Feet.
Intercalated mud-colored shale and sandstone	12
Coarse gray sandstone, with thin streaks and flakes of coal	8
Clayey layer	½
Red, variegated and speckled gray sandstone	10
Hard calcareous layer not continuous	1
Gray and red-brown variegated sandstone	10
Light gray to bluish gray	12+

It will be noticed that the good stone is in the bottom of the quarry and is overlain by a great thickness of poor and worthless material that would not pay for the handling. There is a great deal of stone exposed at this point, and while much of it is imperfect some of it may prove valuable.

In the bluff to the northeast the best stone is at or near the top of the bluff, and, while the stone is not so fine in color and grain as that in the quarry opening, it possesses the merit of being accessible.

The stone down the ravine from the quarry opening contains much iron oxide and lacks homogeneity.

On Mr. Lewbetter's place, in Sec. 26 (19 N., 9 W.), south of the quarry described above, large quantities of sandstone are exposed, in places 50 to 60 feet thick, the most promising looking stone being that on top of the bluff north of the chalybeate spring, where about eight or ten feet of the top of the bluff has a soft gray color, even grain, soft in the interior and hard on the exposed surface, occurring in layers two to three feet thick. The lower part of the bluff consists of yellow ferruginous sandstone with traces of coal.

The Glen.—Considerable sandstone has been quarried for local use at the Glen on Mr. John Rhode's place in the south part of Sec. 14 (19 N., 9 W.). A section of the quarry face at the largest quarry opening shows:

Section at the Glen Quarry, South of Covington.

	Feet.
Soil and clay with sandstone boulders	2
Shelly sandstone with many seams and patches of shale and clay	15
Brownstone	12
Gray sandstone with yellow-brown stripes	8
Gray sandstone with patches of coal and pyrites	6

The brownstone is comparatively uniform in color, but contains numerous iron kidneys, which injure it greatly for building stone.

Down the ravine (west) 75 yards from the above quarry and on the south side of the ravine is another opening in the sandstone from which gray and yellow stone has been taken. The stone is evenly bedded, uniform in grain and texture, but not in color, and would make a good bridge stone. There is a nice looking building stone on the north side of the ravine near the mouth.

Covington.—No sandstone is quarried at Covington. The quarry northwest of the town on the west side of the river is described on a subsequent page. There is an exposure of a few feet of coarse-grained shelly sandstone on the east bank of the Wabash river at Covington, between the wagon bridge and the railroad bridge, the peculiar grain and texture of which are suggestive of the Mansfield sandstone, but there is not sufficient stratigraphic evidence to so classify it at present and it is designated with the unclassified Coal Measures on the map. A finer grained ferruginous sandstone of different character outcrops near the wagon bridge.

Southwest of Portland.—Along the immediate river bluff southwest of Portland (Fountain postoffice) in section 6 (20 N., 8 W.) the massive Mansfield sandstone is exposed 15 to 20 feet thick, light brown in color and containing iron secretions. The heavy covering of drift material (15 to 20 feet) would prevent the economic production of the stone.

Along a small ravine from the southeast in the northeast quarter of section 7 and the northwest quarter of section 8 is an outcrop of buff and yellow sandstone belonging to a horizon above that of the Mansfield stone. It occurs in evenly bedded layers three to four inches thick, with some intermingled shale and shaly sandstone. The rock is soft when first quarried and contains a great quantity of mica. There are several thin layers of hard calcareous sandstone in that branch of the ravine from the southeast. The stone has been quarried for local use at the forks of the ravine in the northeast quarter of section 7 (20 N., 8 W.). As this quarry is not more than one-fourth mile from the Covington branch of the Wabash Railway the stone might have a more extensive use for bridges, foundations, etc.

In the southeast quarter of section 5 (20 N., 8 W.), east of the wagón road, is an outcrop of black shale containing traces of coal. In the northeast quarter of section 5, on the southeast side of the wagon road, is a heavy ledge of Mansfield sandstone which has been quarried a little for local use. Along the old canal in section 12 (20 N., 9 W.) is an extensive deposit of peat that recently burned for several months before it was extinguished by heavy rains. It is said to cover several acres.

Portland (Fountain Postoffice).—There are large exposures of the Mansfield sandstone at Portland. The old Wabash and Erie Canal was cut in the solid rock at this point, and along the south side of the canal the rock wall is 12 to 15 feet high, the tow-path, on which the railway is now placed, being on the north side. Between the railway and the wagon road, running northeast from the town, there are thirty acres or more on which the stone has little or, in some places, no covering, and has been quarried to some extent. Mr. Brooks says he has shipped 500 or 600 perches to Covington in the last four years. The stone has all been quarried near the surface, none of the openings being more than five or six feet deep. The reason the stone has not been quarried to a greater depth appears to be that there are a few bedding seams near the top, while the bottom of the bed is massive and hence not so easily quarried by hand. The greatest objection to the stone, as shown on the bluff and in the small quarry openings, is the lack of uniformity in color, that in the lower part of the bluff being a light gray with occasional brown spots, while in the upper part of the bed there is much brownstone, which, in many places, is two or three feet thick, and in one place ten feet or more. Considerable nice brownstone could be obtained here, but it is not in sufficient quantities to be worked for the brownstone alone, and could only be quarried with profit by having a market for the accompanying gray and variegated stone.

The durability of this stone is shown by the hard compact surface of the natural outcrops, and the appearance of the face cut in the construction of the old Wabash and Erie Canal 50 years or more ago which is discolored and moss grown but shows no sign of distintegration and the pick marks made at that time are plainly visible.

Bear Creek.—Bear creek, which joins the Wabash river at Portland is a comparatively short tributary, yet has quite a variety of rocks in its valley. The mouth of the valley is in Mansfield sandstone at the base of the Coal Measures. Near the middle of its course is an exposure of the Lower Carboniferous limestone above which the Mansfield sandstone occurs again followed by sandstone and shale of the overlying Coal Measures.

The Mansfield sandstone on the lower course of the creek in sections 32 and 33 (21 N., 8 W.) is somewhat similar to that at Portland. It forms bold rugged cliffs 60 to 80 feet high along the creek, the valley in places being a deep narrow canyon. In most places the stone is buff-colored, contains secretions of iron oxide and considerable false bedding, which is quite pronounced at the Arch at the picnic grounds a quarter of a mile south of Portland. "The Arch" is an opening about 15 feet wide and nearly as high through the narrow ridge of sandstone between Bear creek and one of its small tributaries. It is on the outside of one of the sharp curves of the creek, which has here cut back under the bluff until it has made an opening through into the ravine. The cliff is nearly 40 feet high, all of gray and variegated sandstone with patches of iron oxide. On the east side of the road east of the Arch is a small rounded hill of brownstone, the top of which is 40 feet above the road and about 75 feet above the creek The stone has some false bedding and patches of iron oxide and is somewhat shelly, yet there are small areas having a good texture and color. While there is some good stone here it could not be obtained without handling considerable inferior stone. At the east end of this rounded hill is an isolated pulpit rock 20 to 25 feet high and more than 20 feet in diameter. West of the wagon road, between the small rounded hill and the Arch, some variegated sandstone has been quarried, possibly 2,000 cubic feet in all. The quarry has been abandoned for several years.

On Bear creek for a half mile or more above the Arch through the southwest quarter of Sec. 33 (21 N., 8 W.) and the northwest quarter of Sec. 4 (20 N., 8 W.) the Mansfield sandstone forms bold cliffs sixty to eighty feet in height. The stone is massive, yellow, gray and brown in color, contains much false bedding and many iron secretions. Small patches of good stone of uniform grain occur scattered through the defective rock.

Near the section line on the north side of Sec. 4 (20 N., 8 W.) Bear creek has cut quite a narrow channel through the sandstone, which is massive, yellow, even grained, almost free from iron secretions and false bedding, and could be quarried to advantage on the north side of the creek for bridge or foundation stone.

The finest building stone in this valley is just north of the middle of Sec. 4 (20 N., 8 W.) on the lower course of a small tributary known as Rattlesnake, where the stone has a light gray, nearly white color, and a medium, coarse, even grain. It outcrops on both sides of Rattlesnake just south of the small coal bank and in the horseshoe-shaped bluff across the neck between Rattlesnake and Bear creek. This is probably one of the handsomest building stones in the county, but so far it has received no attention. A very little was quarried for local use. The rock shows bedding planes at the surface six inches to ten feet apart, which are probably due to the influence of the weather, and in the interior it is no doubt massive. On the west side of the creek (Rattlesnake) south from the coal bank, there is an acre or more of the stone with very little loose material overlying it, the stone being ten to fifteen feet thick. On the east side of the creek and on the horseshoe bluff the bed is twenty-five to thirty feet thick and is overlain by a drab-colored shale and shelly sandstone. The base of the bed in all the exposures contains much iron pyrites and in places patches of shale, from two to four feet of the stone being injured by these substances.

In a small tributary of Bear creek from the east, just over a narrow ridge north from the mouth of Rattlesnake, there is an outcrop of massive, cross-grained, ferruginous, yellow sandstone, but it contains too many imperfections to have any commercial value.

At and below the confluence of Rattlesnake branch and Bear creek there is an outcrop of impure siliceous Lower Carboniferous limestone containing many geodes and fossil bryozoa.

In the southeast quarter of the northeast quarter of Sec. 4 (20 N., 8 W.) is a fine chalybeate spring in the bed of the creek. A short distance above the spring is a small deposit of handsome yellow ochre, which occurs in a layer three to four inches thick in the creek bank. It is said to form a heavier deposit, now concealed, a short distance up the creek. The sandstone and shales of the Coal Measures outcrop in several places in the southwest quarter of Sec. 4 (20 N., 8 W.). In the northeast quarter of the southeast quarter a short distance below the iron bridge a dark colored, carbonaceous sandstone has been quarried by Mr. Galloway for local use in bridges and culverts. It is not a handsome stone, and is inferior to the Mansfield stone described above, yet it is better adapted to local use for rough bridge stone, as it is stratified and can be quarried more cheaply in small quantities. Shales and clays of different kinds occur on both Bear creek and Rattlesnake in the southeast quarter of Sec. 4 (20 N., 8 W.). An impure, dark colored sandstone and shale outcrops at the cross-roads in the middle of Sec. 10 (20 N., 8 W.) and an impure, yellow-red and variegated sandstone outcrops 200 yards or more southwest of the cross-roads, but it has no economic value.

Between Bear Creek and Shawnee Creek.—There is an outcrop of Mansfield sandstone in a small ravine in the south part of Sec. 27 and the north part of Sec. 34 (21 N., 8 W.). The rock is exposed along both sides of the ravine for nearly half a mile, varying in thickness from five to thirty or forty feet. Much of it contains cross-bedding and streaks of iron oxide, yet small areas occur sufficiently free from these imperfections to furnish a good bridge stone for local use.

Near the middle of the west side of Sec. 27 (21 N., 8 W.) in the bottom of the old canal bed is a small outcrop of shaly Riverside sandstone.

Near the middle of the south part of Sec. 22 and the north part of Sec 27 (21 N., 8 W.) between the railroad and the river is an outcrop of massive buff sandstone, which outcrops for nearly 200 yards along a bayou near the river with a vertical face twelve to fifteen feet high. There would be but a slight covering to remove for 100 yards or more back from the bluff. In places the rock is seamless, and so far as can be seen from the surface, perfectly uniform. In some places there are a few weather seams, along which is a thin coating of iron oxide, that has probably come from the diffused pyrite, which in some places has been in small grains which have oxidized in places, giving the stone a sort of salt and pepper appearance. Some stone has been quarried at this place, probably 8,000 cubic feet or more, said to have been quarried by Jacob Strumpf, of Williamsport, for use in Covington. It is a promising location for a quarry, as there is abundance of good, durable, buff stone that is apparently for the most part uniform in color and texture, and admirably situated for quarrying, being close to the railroad and river, and having very little stripping.

The sandstone outcrops in several places along the railroad through the southeast quarter of Sec. 22 (21 N., 8 W.) as far as the mouth of Shawnee creek.

Shawnee Creek.—Large quantities of Mansfield sandstone are exposed along the lower course of Shawnee creek between Rob Roy and the river, but there is none of any economic value for a half mile or more from the river. There is a considerable area in the south part of Sec. 23 and the north part of Sec. 26 (21 N., 8 W.) in which the Mansfield sandstone has but a very slight covering of drift and soil, being exposed in many places. There being no openings or stream channels cut through it, the character of the rock is uncertain. A drilled well just south of the section line in the northwest quarter of Sec. 26 (21 N., 8 W.) gives the section:

Well section near the mouth of Shawnee Creek.

	Feet.	Inches.
Sand and soil	4	
Sandstone, coarse (Mansfield)	38	
Coal		14
Sandstone, fine (Riverside)	46	
Total	89	2

In and below the small ravine from the southeast in the southeast quarter of Sec. 23 (21 N., 8 W.), the northeast quarter Sec. 26 and the northwest quarter of Sec. 25, considerable quantities of black fissile shale occur, in places being 25 feet or more in thickness. No sandstone of economic importance was observed in this part of the valley. Some of the shale might be utilized for the manufacture of paving brick.

On the north side of Shawnee creek in the southwest quarter of Sec. 24 (21 N., 8 W.), about a mile from the river, there is a bold bluff of the Mansfield sandstone where a great mass (several thousand tons) of rock fell off the face of the bluff two years ago (in 1893), and now lies in large boulders on the bank of the creek. The stone has a light buff color, with faint yellow bands following false bedding in places, and a medium coarse grain, with here and there small patches of a fine conglomerate, the pebbles being no larger than wheat grains. On all the exposed surfaces, both the old moss-grown surface and that exposed by the recent fall two years ago, the rock is very hard—harder than the Mansfield stone in most of its outcrops. At the west end of the mass of debris and down stream from it the sandstone has considerable cross-grain and secretions of iron oxide. At and near the upper (east) end of the freshly exposed bluff the rock is comparatively free from the iron secretions, and almost so from the cross-grain. At this point good bridge stone and possibly good dimension stone could be obtained. The clean, solid, massive stone is twenty to twenty-five feet thick, overlain by from one to ten feet of shelly sandstone and drift soil, and is underlain by a pyritiferous black shale.

About 200 yards (about 500 by the creek) above the fallen rock referred to above, the sandstone has been quarried a little on each side of the creek, possibly 2,000 cubic feet or more. The stone is light gray and buff in color, and in a few places nearly white. In some places are small dark-colored specks of oxidized pyrites giving the stone a salt-and-pepper appearance. A few small streaks of fine conglomerate occur, but do not seriously mar the stone. Some nice stone could be obtained at these openings.

On the west side of the wagon road, 100 yards north of the iron bridge over Shawnee creek, in the southwest quarter of Sec. 24 (21 N., 8 W.) is a large deposit of calcareous tufa (locally called "marl"), which has been quarried for lime-burning. It occurs in regular stratified layers two to ten inches thick, and has been quarried to a depth of twelve to fifteen feet over an area of 600 square feet or more. The bottom is not exposed and the total thickness of the deposit is not known. The stone, while having an open, porous texture, is firm, and has a semi-metallic ring. It seems a little strange that more of this stone has not been burnt into lime, as it is easily quarried, as its porous texture renders it easily burnt and as wood is abundant. It would furnish a remarkably pure lime, and it is only a mile from the C. &. I. C. Railway, and in a region almost devoid of limestone. It is said that plasterers object to its use because "the white coat mixed with it is so tough." This stone will be used with profit sometime.

Deposits of tufa similar to this but in smaller quantity occur in many places throughout the region, where small springs emerging at or near the base of the Mansfield sandstone, deposit the lime carbonate, the deposit in many places taking place at the present time. There is at present no spring at the deposit mentioned above, but probably was at the time of the deposit of the tufa. There is a similar but smaller deposit on the north side of the creek 240 steps above the wagon bridge.

Along Shawnee creek between the wagon bridge in the southwest quarter of Sec. 24 (21 N., 8 W.) and the confluence of Big and Little Shawnee creeks in the northeast quarter of Sec. 25 (21 N., 8 W.) the light gray and buff colored Mansfield sandstone outcrops in several places, lying unconformably on the Riverside sandstone, which in some places is exposed in bluffs 20 or 25 feet high and in other places, close by, lies below the level of the valley.

The Mansfield sandstone outcrops along Big Shawnee creek for a quarter of a mile above its confluence with Little Shawnee. Black pyritiferous shale with thin layers of coal are exposed along the creek bank at the base of the sandstone for nearly 100 yards above the confluence of the two creeks. Near the upper limit of the sandstone on Big Shawnee creek in the southwest quarter of Sec. 19 (21 N., 7 W.) the stone has been quarried to some extent (possibly 500 cubic feet) for local use. The quality is sufficient to guarantee a more extensive production, as the stone is comparatively even-grained, homogeneous in texture, and nearly so in color through considerable areas; some being a light gray, some a buff color. The natural exposures show a smooth face, even grain and sharp corners. Good bridge stone and probably good building stone could be obtained here.

On Little Shawnee creek the Mansfield sandstone outcrops for nearly 100 yards above its confluence with Big Shawnee in a ledge 15 feet thick. A short distance below where the wagon road west from Rob Roy crosses the creek the Mansfield sandstone ends and the underlying shaly Riverside sandstone begins. Where the road crosses the creek the latter stone forms a bluff 40 or 50 feet high, but it has no economic value.

Through the middle of Sec. 30 (21 N., 7 W.) there is no rock exposed, the slopes being covered with drift material. In the southeast quarter of Sec. 30 is an exposure of 12 feet or more of light gray and yellow-colored Mansfield sandstone which has been quarried to some extent at what is known as the Barney Brown quarry. Some of the stone was used for bridges in the vicinity and some was used in Mr Brown's stone house in the southeast quarter of Sec. 30 (21 N., 7 W.) close to the quarry. This house is said to have been built more than 50 years ago, and the mortar has washed out from between the stones, thus giving the building a kind of dilapidated appearance, yet the stone shows no signs of decay. A little more care in selecting the colors might have produced a happier effect. The sandstone outcrops for nearly one-fourth mile south of the quarries, but contains too much iron oxide and false bedding to have any value.

There is a small outcrop of shaly Riverside sandstone on the south side of the creek in the northwest quarter of Sec. 23 (21 N., 8 W.) near the middle of the section. Small exposures of the same stone occur at intervals through the south part of Sec. 24 and the north part of Sec. 25 (21 N., 8 W.), and there are large outcrops of it along both sides of Big Shawnee creek north of Rob Roy through the north part of Sec. 30 and the south part of Sec. 19 (21 N., 7 W.). From less than half a mile east of Rob Roy to the head of Big Shawnee creek no rock exposures were observed, the valley and bordering slopes being covered with glacial drift. The valley is very shallow, the creek appearing to flow over a gently rolling plain. On Little Shawnee creek there is a bold cliff of the Lower Carboniferous (Riverside) sandstone less than a quarter of a mile above its confluence with Big Shawnee. In the southeast quarter of Sec. 30 the Riverside sandstone outcrops underneath Mansfield sandstone and again in small quantities up the creek from the Brown quarry in the northwest quarter of Sec. 32 (21 N., 7 W.). Above this the creek was not explored, citizens reporting no rock outcrop of any kind.

Nave Branch.—The lower course of Nave branch, which runs nearly parallel with Shawnee creek, has no rock exposed. It occupies a wide, shallow, dry, valley bordered by low gravel hills. North of the branch on the east side of the Wabash ("The Towpath") Railway is a quarry in this gravel deposit from which large quantities have been shipped, having been taken from 12 acres or more to the depth of 12 to 15 feet.

The first rock observed in place in ascending Nave branch is near the middle of the north side of section 24 (21 N., 8 W.) just west of the north-south wagon road, where a coarse yellow sandstone (Mansfield) is exposed three to six feet. East of the wagon road the thickness of the exposure increases to 15 feet. About 50 yards east of the road the stone has been quarried a little for local use, but the inferior quality will never justify more than a local usage.

The sandstone outcrops at intervals for a mile and a half further up the creek into the southeast quarter of Sec. 18 (21 N., 7 W.), in places the rock being concealed and in places the sandstone being almost entirely replaced by a black shale. The shale* outcrops in large quantities in the northeast quarter of Sec. 24 (21 N., 8 W.) where it contains some coal, small quantities of which have been mined.

Just east of the C. & I. C. Railway in the northeast quarter of the northwest quarter of Sec. 19 (21 N., 7 W.) is another sandstone quarry from which probably 10,000 cubic feet of sandstone have been taken. Part of it has been used in constructing the stone culvert for the railway

*See the preceding report by the State Geologist for particulars.

across Nave branch. The stone is gray and buff in color and has a few irregular seams and has been quarried to a depth of 10 feet. The stripping is too heavy (six to ten feet) to permit much stone to be quarried here with profit. There is an exposure of Lower Carboniferous sandstone (Riverside) beginning east of this quarry and continuing for a quarter of a mile or more. More than a quarter of a mile east of the quarry in the southeast quarter of Sec. 18 (21 N., 7 W.) is a low ledge of the Mansfield stone, the most eastern exposure observed on this branch. It contains too much iron oxide and false bedding to be of any value.

No outcrop of the Mansfield stone was observed between Nave branch and Attica except a slight exposure near the middle of the west half of section 18 (21 N., 7 W.).

Between Attica and Riverside.—No sandstone was observed to outcrop in the town of Attica, but a very short distance northeast of the town in the northeast quarter of Sec. 5 (21 N., 7 W.) there is a small exposure of shelly Mansfield sandstone of no commercial importance.

Along a small branch from the south in the south half of Sec. 33 (22 N., 8 W.) large quantities of sandstone (Mansfield) have been quarried from one of the largest sandstone quarries in this part of the State. The stone has been quarried on both sides of the ravine for more than a quarter of a mile, through a thickness varying from 12 to 25 feet and back into the hill until the expense of stripping became too great to make further quarrying profitable. The abandoned quarry face shows five to 12 feet of glacial drift and a like thickness of loose shelly sandstone overlying the marketable stone, which is yellow to yellow-brown and greenish-gray in color with small dark specks of iron oxide scattered through it. It is in thin layers at the top of the bed, becoming heavier toward the base, the bedding seams apparently having been opened by the weathering agencies.

There was formerly a switch run into this quarry from the Wabash Railway which passes close to the north end of the quarry, but the switch has been removed and the quarry abandoned for many years. Nothing definite could be obtained in regard to the history of this quarry, as to when it was opened, or when closed or the amount obtained, etc.

The sandstone outcrops along this ravine for a half mile south of the quarry, but the greater part of it has no economic value. Immediately south of the south end of the quarry the sandstone is very cross-grained and ferruginous, but less than a quarter of a mile further south the cross-grain disappears and some nice even-grained sandstone occurs, suitable for building purposes. There is a small outcrop of the underlying Lower Carboniferous sandstone and limestone near the middle of the south half of Sec. 33 (22 N., 7 W.). At the mouth of a small tributary ravine from the east along this outcrop are three small chalybeate springs that emerge at the contact of the Mansfield sandstone with the Lower Carboniferous.

The base of the sandstone here contains much pyrite which probably furnishes the iron for the springs; the upper part of the bed (12 to 15 feet) contains good bridge stone.

For 150 yards or more along the Wabash Railway northeast from where it crosses the ravine above mentioned the road is cut six to ten feet into the shelly imperfect yellow Mansfield sandstone.

At the north end of this rock cut in the small ravine from the southeast is an outcrop of the Mansfield sandstone which extends only a short distance above (south of) the railway until it is replaced by the underlying rocks. As it does not occur north of the railway, it would appear as though the stone occurred at this place in an eroded channel in the Lower Carboniferous rocks.

No other outcrop of the coarse grained Mansfield sandstone was observed between the last mentioned and Turkey run above Riverside. The Lower Carboniferous, Riverside, sandstone outcrops in many places through sections 27, 26, and 25 (22 N., 7 W.), and has been quarried in several places

Riverside Postoffice (*Independence Station*).—At Riverside postoffice in the northeast quarter of Sec. 26 (22 N., 7 W.) are two large sandstone quarries, one of which is not in operation at present (1895). This is an entirely different rock from the Mansfield stone, both in its lithologic character and its geologic position. It belongs in the Lower Carboniferous system, and is named from this locality where there is a good, accessible, typical exposure.

It corresponds lithologically with the Knobstone group near the base of the Lower Carboniferous, and possibly belongs to that group, but not enough areal or paleontologic work was done to definitely determine its position in the geologic column further than that it is Lower Carboniferous, and lies unconformably below the Coal Measures.*

It is a very fine grained sandstone, blue on a fresh surface, weathering buff to dark gray on long exposure. It is quite evenly stratified, in many places on natural exposures the stratification planes becoming quite abundant, even grading into shale. In the quarry there is a little shelly material at the top, below which the stone occurs in layers 16, 17, 18, 19, 20, 22, and 42 inches thick, with thinner layers near the top of the quarry. The stone works easily and splits nicely, either with the bedding or across the grain. The layers are loosened from the floor by wedges, and can then by drilling a series of holes along the desired line of break and inserting wedges (plugs and feathers) be split almost as straight and even as if sawed. A steam drill is used for making the holes, and formerly all the stone was so wedged off; but recently the Knox blasting system has been used with a little saving of labor and

* It has been referred to in former State reports as the Chester sandstone, but sufficient evidence was not found either in the reports or in the field to justify such a classification.

increased injury to the stone. The company intends using the Githens system the coming season. Owing to the homogeneous fine grain the rock will take a very smooth finish, and can be used for delicate carving and tooled work.*

The average thickness of the marketable stone is about fifteen feet, and the maximum thickness of the quarry face twenty-seven or twenty-eight feet. The quality of the stone improves as the quarry is worked further back into the hill; that is, there is more of the blue stone, which commands a better price than the buff, and there is less shelly sandstone, but the overlying glacial material increases in thickness

A chemical analysis of this stone, made for the Survey by Dr. H. H. Ballard at Rose Polytechnic Institute, shows its composition to be as follows:

Analysis of Riverside Stone.

	Per Cent.
Insoluble residue	93.16
Alumina (Al_2O_3)	1.60
Iron oxide (Fe_2O_3)	2.69
Lime (CaO)	.13
Total	97.58

While the iron was determined as ferric oxide, as is customary, it does not exist in the stone as such, but as diffused carbonate and possibly some sulphide. It is probably this protoxide or lower oxide of iron that gives the fresh stone its blue tint, and its oxidation into the higher or sesquioxide form that gives it the buff tint. This is a partial element of weakness in the stone, but not a serious one, as the iron is present only in small quantity and is finely diffused, so that it undergoes a gradual oxidation without serious injury to the stone; in fact, where the stone is placed in a dry position, as in the walls of buildings, this oxidation is a process of centuries, simply causing the stone to "mellow" with age The only other element of weakness in the stone is the alumina which is liable to absorb water and cause the stone to burst on freezing, but this is not present in sufficient quantities to be a serious injury to the stone, for while the percentage is higher than in the Mansfield stone it is much lower than in many sandstones famed for building stone. [See tables in final chapter for comparison.]

The microscope shows [See Plate 11] the occurrence of many angular quartz grains, which make up the bulk of the insoluble residue, some muscovite, biotite, feldspar, calcite, and limonite. The stone is much

*The workmen state that the stone has a peculiar action on the tools, viz., the smooth-edged drove and splitting chisels soon becoming toothed by use. This stone is known to some extent locally as freestone, not within the meaning commonly assigned to freestone, namely, a stone that works freely in all directions, but because it is supposed to contain many impurities.

finer grained than the Mansfield stone, the average size of the grains being 0.07 millimeters in diameter, the largest measuring 0.13 mm. (see p. 204 for comparison). The constituents are intimately mixed, making the stone homogeneous throughout.

Crushing tests made on this stone for four specimens gave a strength of 6,000, 6,090, 6,100 and 6,800 respectively.† This, as will be observed from consulting the tables in final chapter, is about the average for common sandstone.

Absorption tests on two specimens of the blue stone gave 4.8 per cent. and 6.8 per cent. respectively, and on the buff stone 5.8 per cent. and 6.1 per cent.

The homogeneity of the Riverside stone, its pleasing color, the smooth finish of which it is susceptible and its adaptability to fine carving, will no doubt cause an increasing demand for this stone as its properties become better known.

Stone in small quantities is said to have been quarried here fifty years or more ago. Quarrying on the present enlarged scale has been carried on since 1887, when the quarry now in operation came into possession of the present company, Guyer, Burchby & Co. It has been worked over an area of about three acres, yielding an average thickness of about twelve feet of sound stone.

It has been shipped to Lafayette, Indiana; Decatur and Peoria, Illinois; St. Louis, Missouri, and Detroit, Michigan, more going to Lafayette than to any other point. At Lafayette it has been used in the High School building, in the electrical building at Purdue University, in many private dwellings and in the Brown-street bridge.

There is another quarry belonging to the Riverside Stone Co., a quarter of a mile west of the Guyer, Burchby & Co. quarry in the same bed of stone, which differs little in quality, but there is much more of the loose shelly stone at the top, making much more waste material to handle, so much in fact that it is doubtful if much more stone could be lifted with profit. Considerable stone has been taken from this quarry, the excavation being larger than at the other quarry; and it has apparently been well equipped for work; the stone was sawed into trimmings and dimension stone in a mill located at the quarry. It is not in operation this year (1895).

There is a great deal of Riverside stone exposed along the Wabash Railway both east and west from the Riverside quarries, and while in

† Mr. Howe, of Rose Polytechnic Institute, who tested the stone, states that the specimens "although appearing quite true in surface were found to be quite the contrary when placed upon a steel plate. Not over 75 per cent. of the area was in contact with the plate in any case." So that the above probably represents considerably less than the maximum strength of the stone.

many places it is shelly and crumbling on the weathered surface, yet in a few places it is sufficiently sound to indicate fairly good building stone.

Turkey Creek.—Turkey creek is a small tributary of the Wabash east of Riverside in sections 19, 30, and 29 (22 N., 6 W.). Its lower course is in the Riverside sandstone, and the upper part in the Mansfield sandstone The latter stone in this valley has no commercial value, being thin-bedded to shaly, containing much iron oxide and disintegrating on exposure. It rests unconformably on the Riverside stone, the accompanying figure (Fig. 4) showing where it has filled in an old erosion

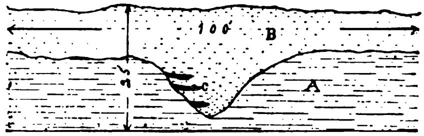


Fig. 4. Section showing the contact of the Carboniferous and Lower Carboniferous rocks on Turkey Creek.

A—Riverside sandstone (Lower Carboniferous).
B—Mansfield sandstone (Coal Measures).
C—Basal conglomerate.

channel The Riverside stone where observed in this valley is too shaly to have any value

Grindstone Creek—Grindstone creek is another small tributary of the Wabash lying east of Turkey creek and nearly parallel with it, in sections 20, 21, and 28 (22 N., 6 W.). The rock exposures are similar to those on Turkey creek, but there are larger exposures of the Mansfield sandstone. It outcrops almost continuously from the section line near the middle of the west side of the southwest quarter of Sec. 21 (22 N., 6 W.) south to within a quarter of a mile of Robert's postoffice in the middle of the south side of Sec 28 (22 N., 6 W.). None of the stone along the creek so far as observed has any economic value. South of the wagon bridge in the northwest quarter of Sec. 28 (22 N., 6 W.) there is some fairly good stone, but it is covered by too much waste material to be quarried with profit. Some stone has been quarried on the hill west of the creek in the middle of the west half of Sec. 20 (22 N., 6 W.).

The best outcrop of sandstone in this part of the county is on the flat east of Grindstone creek in the middle of Sec. 21 (22 N., 6 W.) at Mr. Martin's stone quarry, where stone was obtained for the wagon bridge over Flint creek and where some has been quarried for foundations. It has been worked to a depth of six or eight feet, but no opening has penetrated to the bottom of the bed so that the total thickness is unknown. The prevailing color of the stone is light gray, in places stained a yellow-brown. It occurs in somewhat regular layers two to three feet thick.

There is, in places, no stripping, in some places a few inches of soil and shelly sandstone, but the cost of stripping over several acres would be very slight. If this stone should prove to retain its homogeneity through any considerable thickness it would be a promising opening for a quarry.

This deposit apparently rests unconformably on the Lower Carboniferous rocks and has a northeast-southwest trend, extending southwest probably to Grindstone creek, and outcropping only a hundred yards or so northeast of the quarry. This appears to be the eastern limit of the Mansfield sandstone on the south side of the Wabash river. Small isolated patches may occur in places along the western part of Tippecanoe county, but none were reported and the region was not traversed.

The Riverside sandstone, in some places more calcareous, in others more shaly than at Riverside, outcrops along the lower course of Flint creek. On the south bank of the Wabash river a half mile or more below the mouth of Flint creek in the Burnett reservation is a large deposit of broken chert known as the Flint quarry, which has been quarried in large quantities and shipped to Lafayette and elsewhere for road material. It was formerly loaded on flat-boats and shipped on the Wabash river. It is now (1895) shipped by rail.

The North Side of the Wabash River.

The area of the Mansfield sandstone north of the Wabash river is practically limited to Warren county.* It outcrops along the river bluffs in many places from Black Rock on the eastern border of the county to the mouth of Redwood creek well to the west side of the county. There are also numerous exposures along the tributaries from the north, as Little Pine, Kickapoo, Pine, Rock and Redwood creeks. The upper limits of the deposits on some of these creeks is not clearly defined, being concealed by the heavy bed of overlying drift. This is especially true on Kickapoo creek. In the eastern part of the county the northern limit of the formations in the creek basins is near the tops of the hills, where it is replaced by the underlying Lower Carboniferous rocks; in the western part of the county the northern limit is at the base of the hills, where it disappears beneath the overlying rocks of the Coal Measures.

The irregularities of the outcrop in the eastern part of the county are largely due to unconformity by erosion at the base of the deposit, that is, previous to the deposit of Mansfield sandstone, there had been an elevation and erosion of the land followed by a depression of this area when

*Tippecanoe county was not traversed and it is possible that small exposures of the sandstone may occur in that county, but if so they are isolated from the main body. Some of the county reports mention its occurrence, but give no localities.

the Mansfield sandstone was deposited in the eroded channels and inequalities of the old land surface. Particular instances of this unconformity are mentioned on the following pages.

In Sec. 27 (20 N., 9 W.), across the river from Covington, between the I., B. & W. railway and the river, are several small quarries in the sandstone of the Coal Measures. Sandstone has been quarried here at intervals for several years, but the stone is of inferior quality and has never had more than a local use and probably never will. In most places it is very thin-bedded, grading into shale, and associated with considerable quantities of shale. East of the quarries apparently the black shale replaces the sandstone entirely, forming a very heavy bed containing much iron pyrites and some coal.

Northwest from these quarries along the railway is a heavy bed of gravel, from which large quantities have been shipped. It will no doubt continue to furnish gravel for many years yet.

Redwood Creek.—Sandstone of local value outcrops below (southwest of) Redwood creek, but it all belongs to a higher horizon than does the Mansfield sandstone, and is interspersed with productive beds of coal. In the southwest quarter of Sec. 3 (20 N., 9 W.) is a deposit of Carboniferous sandstone that has had a local use for grindstones.

The Mansfield sandstone outcrops in bold bluffs 40 to 50 feet high along the lower course of Redwood creek, in sections 1 and 2 (20 N., 9 W.) and Sec. 35 (21 N., 9 W.). It varies from light gray to yellow in color, contains much segregated iron, many lenticular shaly patches, and is in most places, more or less, cross-grained. Owing to these defects, it is doubtful if the stone will ever have more than a local use. There are small areas of good stone, strong, durable, and homogeneous, but all such occurrences grade rapidly into imperfect stone, both laterally and vertically.

Small quantities of stone have been quarried above the wagon bridge in the northwest quarter of Sec. 1 (20 N., 9 W.). Stone from the immediate vicinity was used in the abutment at the east end of the bridge above mentioned. The abutment at the west end is the rock in situ. This bridge was constructed in 1876, and the rock as yet is unaffected by the weather, except in being discolored, as it darkens on exposure.

At the "Hanging Rock," about a quarter of a mile above the bridge, the cliff is undermined by the creek, the upper part jutting out 15 or 20 feet over the water. The stone at this point contains many reticulated veins of iron; the sandstone between the veins standing out in relief gives the face of the cliff a very picturesque appearance. It has been referred to by a previous writer as the "Pictured Rocks."

The sandstone disappears beneath the creek bed near the middle of the north half of Sec. 35 (21 N., 7 W.), and is succeeded by a bed of black limestone that would furnish a black marble of fair quality. The bed is three feet thick where exposed on the creek bluff and it is apparently solid; where exposed in the creek bed a few yards above there are two layers eight and ten inches thick respectively.

The effect of the weather on the outcrop appears to be (1) to change the coal-black color to a dull gray, due no doubt to loss of bitumen and (2) to cause the opening of the joints. Otherwise the stone withstands the weather much better than most black limestone. No use has ever been made of this stone as far as known. It is underlain by a bed of black shale 15 to 20 inches in thickness that lies unconformably on the Mansfield sandstone. The shale is very pyritiferous and contains many secretions of clay ironstone, etc.

There is a small exposure of sandstone up the creek (east) 100 yards or so from the marble, and another small exposure more than a half mile further north in the northeast quarter of Sec. 26 (21 N., 9 W.), above which the slopes are covered with glacial drift.

Rock Creek.—No exposure of the sandstone was observed between Redwood and Rock creeks, the low bluffs being covered with drift and the river bottom with alluvium.

On Rock creek the lowest outcrop observed is in the north part of Sec. 29 and the south part of Sec. 20 (21 N., 8 W.), where for nearly half a mile along the creek there are bold jutting cliffs of gray and yellow sandstone, twenty to twenty-five feet thick. At the mouth of a small tributary from the north, known as Rattlesnake, where the stone has been quarried in small quantities, the opening shows fifteen to eighteen feet of fairly good stone, which has a nearly uniform gray color, and occurs in irregular layers from three to thirty inches thick Bridge and foundation stone might be obtained here sufficient to supply the local demand. On the south side of the creek, a hundred yards above the quarry, the base of the sandstone cliff contains a layer of coarse conglomerate and lenticular masses of coal. A similar exposure occurs on the same side of the creek 200 yards or so below the quarry, where the conglomerate occurs in irregular masses an inch to three feet thick, with streaks of coal two to three inches in thickness. At the base of the conglomerate are a number of nodular masses of clay ironstone, four to eight inches in diameter, and containing imprints of many fossil leaves remarkably well preserved.

The Mansfield sandstone outcrops more or less continuously for more than two miles above the quarry mentioned, nearly to the Wabash Railroad, in the south part of Sec. 7 (21 N., 8 W.). About the middle of the west side of Sec. 20 (21 N., 8 W) is a considerable quantity of calcareous tufa deposited on the face of the sandstone cliff, large boulders from which have broken off and now lie scattered along the creek bank. Lime for local use might be burned from this tufa.

Through the northeast quarter of section 19 and the south part of Sec. 18 (21 N., 8 W.) there is considerable shale accompanying the sandstone, both underlying and overlying it. It apparently overlies it unconform-

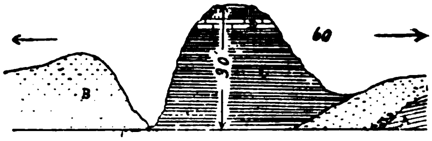


Fig. 5. Section on Rock Creek, Warren County, Indiana.

B—Mansfield Sandstone.
C—Black Shale.
D—Black Limestone (Marble).

ably, as shown in the accompanying figure (Fig. 5). In this overlying shale, just north of the wagon road in the southeast quarter of Sec. 18 (21 N., 8 W.), near the top of the outcrop is a bed of black limestone, somewhat similar to that mentioned on Redwood creek, but not so compact and uniform in texture. Small quantities of black marble might be obtained, but the outcrop would not promise it in commercial quantities. Sandstone of inferior quality has been quarried in small quantities in the ravine from the northeast at the upper end of the shale bluff in the southeast quarter of section 18. The sandstone above this point has but little economic value, even for local use.

Between Rock Creek and Williamsport.—For a mile or more above Rock creek, toward Williamsport, there is but little sandstone exposed, the broad river bottom merging gradually into the gentle drift-covered slopes of the highland. There are a few small exposures of shelly sandstone along the small tributaries, known as Dry branch and Clear branch, in sections 20, 21, 16 and 17 (21 N., 8 W.), but none of any economic value. Wells in that area penetrate sandstone after passing through a thickness of drift varying from eight to thirty feet or more.

Beginning on the north side of Sec. 22 (21 N., 8 W.) and continuing along the river bluff, outcropping the greater part of the way, to the town of Williamsport, is a heavy ledge of Mansfield sandstone. In the ravine in the north part of Sec. 22 and the south part of Sec. 15 (21 N., 8 W.) the stone has a brown to red-brown color, but it is very cross-bedded and more or less shelly throughout, and has little if any commercial value. North of the road, in Sec. 15, the stream has cut a channel or gully in this brownstone six to ten feet deep and three to ten feet wide for 200 yards or more. On the south side of the road the brownstone outcrops about 200 yards, beyond which the bluff is covered with gravel and sand. Through the southeast quarter of Sec. 15 (21 N., 8 W.) and the northwest quarter of Sec. 14 the gray and buff sandstone outcrops in considerable quantities between the wagon road and the river. The many small watercourses cutting back into this bluff give the sandstone ledge a very sinuous course. The bluff was not followed through its whole length, but where observed it contained too many iron secretions and lacked the necessary homogeneity to make it valuable for building stone.

At the mineral spring in the south part of Sec. 11 (21 N., 8 W.) the bed of sandstone is 35 to 40 feet thick, and rests unconformably upon a bed of black and drab-colored shale. The base of the sandstone is very ferruginous, the iron oxide probably being oxidized iron pyrites from which the spring derives the iron with which it is charged. The ferruginized water-soaked base is soft and partially disintegrated, but the upper part is hard and firm. Between the spring and the town the massive sandstone forms a ledge near the brow of the bluff, from which massive boulders have broken away and lie strewn along the slope. Stone has been quarried in small quantities from this ledge in several places.

Williamsport Quarry—The quarry of the Williamsport Stone Co. is on the south bluff of Fall creek, at the school-house, near the middle of the town of Williamsport. The quarry has been opened for many years, said to have been first used about 1840, but it was in May, 1893, that the present company began work on a large scale with modern machinery. Previous to this date it had been worked at intervals by hand to supply the local trade. The stone at Williamsport belongs to the Mansfield formation and rests unconformably upon a bed of carbonaceous, partly conglomeratic shale. The sandstone at the quarry is 50 feet thick at one end of the quarry, being clean, solid, massive stone through the entire thickness, except two or three feet of soil and somewhat shelly rock at the top. At the other end of the quarry the shelly rock extends through two channel cuts to a depth of 10 or 12 feet. On the best face there are seven channel cuts, each about six feet thick. The natural rock face at the west end of the quarry is more even, firm and regular than the channeled face. The only markings on the 50-foot face are a few incipient weather seams parallel with the bedding, all indicating a stone of remarkable homogeneity, which, however, is local, as at the east end of the quarry there is considerable shaly material, and the natural exposure near the end shows local variations in texture. Less than 100 yards west of the quarry the outcrop in the creek bank above the fall shows several feet of shelly and very cross-grained stone.

The stone has a buff color, and when first quarried has a yellow tint, but on drying becomes much lighter, ending in a light gray or faint buff in the seasoned stone. The chemical analysis shows it to be highly siliceous.

Chemical Analysis of the Williamsport Stone.

	Per Cent.
Residue insoluble in HCl	98.57
Ferric oxide (Fe_2O_3)	0.65
Alumina (Al_2O_3)	0.05
Lime (CaO)	0.02
Total	99.29

The insoluble residue is white and consists mainly of quartz, but not entirely so, as the microscope shows the presence of feldspar fragments. The feldspar is mostly microcline, and while not abundant occurs in appreciable quantity. Muscovite, limonite, zircon, and rutile are also distinguishable in small quantities in the microscope.

The quartz grains are smaller than in the brownstones, the average size, being .19 millimeter in diameter, and the largest .32 millimeter. The grains are all sharply angular and in some places are bound together by a silicious cement. In some instances the silica appears to be a secondary enlargement of the quartz crystals upon which it is deposited. Possibly ten per cent. or more of the quartz shows that it has been subject to strain. This, along with the occurrence of the microcline, is suggestive of the probable derivation of at least part of this material from a region of metamorphic rocks.

The stone when green is soft, easily cut or broken, but hardens on seasoning. It is channeled one way in the quarry (using the Bryan channeler), while the blocks are separated the other way by using the Knox system of blasting. The large blocks are then lifted from the quarry and placed in the saw mill and sawed while green.

The stone is used for dimension stone, bridge stone and rubble. The product for 1894 was 111,000 cubic feet, proportioned as follows: building stone, 45,000 cubic feet, bridge stone, 11,000, and rubble, 55,000 cubic feet. The market is mostly along the Wabash Railway between Toledo, Ohio, and Taylorville, Ill. The Methodist church erected in Williamsport last summer (1895) was constructed of the Williamsport stone.

Between Williamsport and Attica no sandstone was observed on the north side of the Wabash river. In the river bluff are considerable exposures of Lower Carboniferous drab-colored sandstone and shale corresponding in position to the Riverside sandstone described above. Small quantities of limestone are associated with this sandstone in the vicinity of Williamsport, but it has no economic value. The formation is in most places too shaly to have any value, but in a few places it has been quarried for building stone, the most productive point being on the wagon road a quarter of a mile northwest of the bridge at Attica, where it has been quarried for several years by Jacob Schmidt. The product is partly used in Attica and vicinity and part shipped to points in Illinois along the Wabash Railway.

Pine Creek Valley.—The lower course of Pine creek is in the Lower Carboniferous rocks, the middle and upper course as far as Rainsville and beyond, in the Mansfield sandstone, and still further north, again in the Lower Carboniferous rocks; about the headwaters, however, the rocks are mostly concealed by the glacial drift. There is but little of the Mansfield stone in this valley of much value as building stone, yet stone of good quality occurs in a number of places, and in many places it is adapted for local use as a bridge or foundation stone.

The Riverside, or Lower Carboniferous, sandstone forms some bold cliffs along Pine creek both above and below the mill pond in the east side of section 36 (22 N., 8 W.) about a mile from the mouth of the creek. The outcrop just below the dam is 60 feet thick, the stone lying in regular. evenly bedded layers two to four inches thick at the top and 20 or 30 inches at the base. It has a blue tint more pronounced than in most localities where this stone occurs. It has been quarried in small quantities and possibly will be in larger quantities. At this point, near the mill pond, it is overlain by a heavy bed of excellent gravel and the stone could be quarried economically only by making use of the gravel at the same time, which might well be done. The stone has been quarried in small quantities both up and down the creek from the dam. The outcrop continues for nearly two miles above the dam.

A small outcrop of the Mansfield sandstone occurs on the wagon road along the border of the French reserve in the southeast quarter of Sec. 36 (22 N., 8 W.) where it has been quarried in small quantities. The stone is too imperfect to have more than a local use.

In the northwest quarter of Sec. 35 and the southeast quarter of Sec. 27 (22 N , 8 W.) on the west side of the creek is a heavy deposit of the Mansfield sandstone 25 to 40 feet in thickness. It occurs in regular layers 8 to 30 inches thick, in some instances with a thin layer of shale or clay between the layers. In one place there is a lenticular mass of blue-black shale 10 to 15 feet thick inclosed in the sandstone. The sandstone resembles that in the Bernhart quarry described later, but is less uniform and even in texture, in places showing much cross grain. Near the upper end of this cliff in a small ravine from the west, on the land of Mr. McCabe some stone has been quarried for local use. The exposure is 18 to 20 feet thick underlain by black shale. The stone is yellow and light gray in color and comparatively uniform in texture and would be a good durable stone for buildings, foundations, or bridges. The supply that could be lifted economically is limited, but is probably sufficient to supply all the local demand.

In the immediate vicinity of the Indiana Mineral Springs in section 23 and the east side of Sec. 22 (22 N , 8 W.) the slopes are covered with glacial drift which forms very steep bluffs in places on the creek bank 75 feet or more in height

On the lower part of Fall creek in the west side of section 22 and the east side of section 21 is a heavy deposit of the Mansfield sandstone accompanied by black shale. The stone varies in texture, and in the channel and bluffs at the "Narrows" of Fall creek the lack of homogeneity is shown by the numerous irregular cavities in the rock. This is a rather picturesque and romantic spot, with the irregular massive sandstone cliffs almost touching each other and overshadowing the very irregular pot-holed bottom of the creek. South of the "Narrows" a coal bank has been opened in the Productive Coal Measures, but there is no sandstone of any importance.

At the mouth of Fall creek the coarse sandstone is below the bed of the creek and is overlain by a heavy bed of black shale which forms a bold cliff on Pine creek below the mouth of Fall creek. At the old mill on Pine creek just above the bridge the sandstone outcrops in the creek, but is very cross bedded and charged with iron secretions. On the east bank of the creek, about a quarter of a mile above the mill, the stone has been quarried for local use. It occurs in a massive ledge 12 feet thick with the prevailing color light gray near the south end of the quarry, becoming more yellow in passing northward along the bluff. Good stone for bridges and foundations could be obtained here. Underlying the heavy ledge of good stone is a bed of shelly, cross-grained, disintegrating sandstone.

From the quarry above mentioned to the bridge across Pine creek, in the northeast corner of Sec. 16 (22 N., 8 W.) there are heavy ledges of sandstone exposed on both sides of the creek. In most places it contains iron secretions and cross-bedding, yet interspersed through this imperfect stone are patches of even-grained homogeneous stone well suited for building purposes if properly selected, and occurring in sufficient quantities to supply all local demands. About a quarter of a mile south of the bridge is an outcrop of excellent yellow and light gray building stone which might be quarried in large quantities. The stone in the bluffs at the bridge contains too many defects to make a valuable building stone. There is a bold cliff of massive Mansfield stone at the spring less than a quarter of a mile above the bridge on the west side of the creek, but it is highly impregnated with iron. In the ravine from the west at the upper end of this cliff, in the southeast quarter of Sec. 9 (22 N., 8 W), the stone is more homogeneous in color and texture and some good yellow sandstone occurs, the watercourse having a channel 15 to 20 feet deep cut into it. Yet it is doubtful if much good stone could be economically obtained at this locality owing to the heavy deposit of glacial drift overlying it.

Through the east and north sides of Sec. 9 and the southwest quarter of Sec. 4 (22 N., 8 W.) the sandstone is exposed in large quantities, much of which is suitable for bridge or foundation stone, but which has too much iron and cross-grain for good building stone. Less than a quarter of a mile above the mouth of Honey branch on the east side of Pine creek is a small quarry with a face of 12 to 15 feet of yellowish gray massive sandstone with considerable variegation in color. Small quantities have also been quarried on the west side of the creek at the same place. For a distance of more than a quarter of a mile in the southeast quarter of Sec.

4 (22 N., 8 W.) the slopes are covered with glacial material and no sandstone is exposed. Beginning at the middle of the south side of section 4 and continuing west for more than a quarter of a mile the sandstone forms a bold bluff and is of fair quality; while it contains considerable cross-bedding it weathers evenly and could be used for heavy masonry. In the southwest quarter of Sec. 4 (22 N., 8 W.) the sandstone bluff terminates abruptly in a bed of black shale. It is not clear whether this is simply a discordance in deposition or whether it denotes unconformity by erosion. On one side of a fairly sharp nearly vertical line is an exposure of 30 feet of black carbonaceous shale containing clay ironstone and on the other side 15 feet or more of massive sandstone overlain by glacial drift. The black shale continues for a quarter of a mile or more up the creek when it gives way to sandstone.

For a distance of nearly a mile through the north half of Sec. 4 (22 N., 8 W.) no sandstone of even local value is exposed, and in fact very little rock of any kind appears, the region being covered with drift.

Near the middle of Sec. 33 (23 N., 8 W.) the sandstone occurs in a massive ledge and thence outcrops most of the way on one or both sides of the creek to the middle of Sec. 23 (23 N., 8 W.), a distance of about four miles Near the south end of this exposure the stone has been quarried on both sides of the creek. mostly on the west side, on property said to belong to Mr. Frye. The thickness of the ledge quarried is about five or six feet, probably about five thousand cubic feet in all having been removed. The stone has a variegated yellow color and is marked by a series of alternating gray and yellow narrow bands that are exceedingly intricate in their contortions and foldings, resembling the contortions often observable in the gneisses of metamorphic regions, but probably due to an entirely different cause.

Sandstone of a fair quality has been quarried on the north side of Sec. 33 (23 N., 8 W.) a hundred yards or so above the old mill, also a half mile further north on the east side of Sec. 23 and at various points at and on each side of Rainsville. At Rainsville the stone contains much segregated iron and much cross-bedding. The bedding surfaces where exposed in several places contain beautiful ripple marks. Some fair bridge stone occurs at a small quarry on the north side of the creek, on the east side of Sec. 22 (23 N., 8 W.). At the upper limit of the outcrop observed near the middle of Sec. 23, the stone is too friable to be of any value.

In the northwest quarter of Sec. 24 (23 N., 8 W.) is an outcrop of the underlying Lower Carboniferous shaly sandstone, above which no rock exposures were observed. The valley becomes shallow and is bordered by gentle drift-covered slopes. In the brief time at our disposal, we were unable to obtain any well sections in this vicinity and the partings shown on the map for this locality are somewhat indefinite.

The Mansfield sandstone is exposed in several places on Mud Pine creek in sections 33, 28, and 29 (23 N., 8 W.), and has been quarried for local use in bridges and foundations in Sec. 33 by Mr. Chas. A. House. The stone contains much cross-grain and is more or less variegated throughout. While it shows evidence of durability and may be used safely in bridges, it is not a desirable building stone. Shaly micaceous sandstone, black shale and coal belonging to the productive Coal Measures, outcrops in Sec. 29 at several points. The coal is mined in one place, but the sandstone has no value for building purposes.

At Mr. House's quarry in the northwest quarter of Sec. 33 (23 N., 8 W.) is a natural curiosity that has attracted many visitors. It consists of a "Table Rock" in the middle of the creek, and is an isolated remnant of the rock left by the creek which has cut a channel on either side of it. The top contains about 400 square feet and is ten to twelve feet above the bed of the creek. The surface of the rock in this locality has been scraped by the glacier and shows the glacial grooves and pot holes.

Bernhart's Quarry, Attica.—About a mile north of Attica on the C. & I. C. Railway, and east of Pine creek is one of the largest sandstone quarries in this part of the State. While the stratigraphy is not perfectly clear there is good reason for believing that this quarry is in the sandstone of the Mansfield period that rests quite unconformably on the Lower Carboniferous sandstone. It is unlike the Mansfield stone in most, though not in all, places in that it is not massive, but occurs in regular layers frequently separated by partings of black shale. The shale is more abundant in some parts of the quarry than in others. The layers vary in thickness from a few inches to six feet. The total thickness of the stone on the quarry face is about 50 feet, and in two places it has been worked 12 to 15 feet deeper. The stone has a buff color and medium coarse grain, is homogeneous in color and texture, is easily quarried and quite durable. It is nearly all used for bridges and culverts along the Wabash Railway, and small quantities in wagon bridges and foundations. It was opened about 1856, and is said to have been in almost continuous operation since that date. Mr. F. J. Bernhart has controlled the quarry since 1892, and his father for 14 years previous to that date.

Kickapoo Valley.—The stone in the Bernhart quarry appears to be isolated more or less from other outcrops of the same stone. A small exposure of stone similar to that described above occurs along the railway in the northeast quarter of Sec. 31 (22 N., 7 W.), and a larger outcrop occurs along the railway north of the Attica-Independence wagon road in sections 29 and 20 (22 N., 7 W.), but the Lower Carboniferous (Riverside) shaly sandstone outcrops on the bluff on each side of the Bernhart quarry; in the valley no rock is exposed. The largest vertical exposure of the Mansfield stone in this valley is at Kickapoo Falls, about a quarter of a mile below Kickapoo station. The little watercourse has cut a ravine, or crescent-shaped cove back into the sandstone which surrounds it with a vertical wall 80 feet high, there being about 60 feet of massive sandstone underlain by 20 feet of black and drab colored shales. The lower 20 feet of the sandstone tends to disintegrate and exfoliate, the upper 40 feet or more being very firm and presenting a nearly even regular face. Near the middle of the crescent and at the top of the cliff is the remnant of a large pot hole.

The outcrop of the sandstone is continuous from the falls up to the Indiana Greenstone Quarry, near Kickapoo station, where the C. & I. C. Railway has cut an opening through the sandstone about twenty-five feet deep, and it is on the side of this rock-cut that the quarry is located, and the one derrick serves to lift the stone from the quarry and place it on the cars. The stone is somewhat similar in texture to that at Bernhart's quarry, but it is not so evenly bedded, contains no shale partings, and does not have such a uniform color. At the north end of the quarry there are some iron secretions that injure the beauty of the stone. The color varies somewhat in different portions of the opening. While in general a straw yellow is the prevailing color, in some portions it has a distinct greenish tint, from which the quarry is named, and on the point next to the creek east of the railway it is nearly white. Considerable stone has been taken from this quarry and shipped to various points along the C. & I. C. Railway for bridge and foundation stone.

The sandstone occurs in large quantities in the ravine from the north and west at the upper end of the Greenstone Quarry, extending to the section line between Secs. 19 and 20 (22 N., 7 W.). At the upper limit of the stone on this branch are some picturesque rapids and falls, where the water is cutting the channel in the sandstone. On the west side of this ravine near the mouth, and not far from the Greenstone Quarry, is a quarry opening, which apparently was worked to some extent several years ago, but is not now in operation.

No outcrop of the Mansfield sandstone was observed on Kickapoo creek above Kickapoo Station. Black and blue shale are exposed at several points a mile above the station, and elsewhere, so far as observed, the region is covered with a heavy deposit of glacial material. Some well sections show ninety feet of drift.

Between Kickapoo and Little Pine Creeks.—The occurrence of the sandstone on the north side of the river over this area is even more patchy than on the south side. Three exposures occur between Kickapoo creek and Independence. At what is known as the Steadman quarry, in the southeast quarter of Sec. 29 (22 N., 7 W.), the stone has been quarried to considerable extent, but not recently. The stone occurs in the river bluff about 200 yards or less from the river channel. The total thickness of rock exposed is thirty-five feet, the base being concealed below the drainage level. There is practically no covering of drift or soil near the edge of the bluff, but the upper eight or ten feet of the sandstone are shelly in places, the remainder of the rock exposed occurring in layers three or four feet thick, but the layers are not regular. Yellow and yellow-gray are the prevailing colors. The uncertainty of the extent of the sandstone in this locality is due not simply to the unconformity at the base, but as well to the glacial or preglacial erosion at the top. A well on the bluff back of the Steadman quarry, not a quarter of a mile from it and but forty feet above, is said to be 110 feet deep, forty-five feet in gravel and sixty-five feet in fine sand, with no solid rock.

There is another small exposure of sandstone of medium quality that has been quarried in small quantities on the McAdams property in the southwest quarter of Sec. 28 (22 N., 7 W.), and a slight outcrop in the northeast quarter of section 28, but they are of only minor local importance.

In the vicinity of Independence large quantities of the Riverside sandstone and shale (Lower Carboniferous) are exposed, but it is all too shelly apparently to have any value.

On each side of the river at Independence there are a great many large crystalline glacial boulders, that are so abundant in places as to prevent the tilling of the soil. The largest of these boulders, known locally as College Rock, occurs at the school-house on the west side of Sec. 22 (22 N., 7 W.), and is approximately 12 x 14 x 10 feet above the surface; the dimensions beneath the surface are not known. So far as known this is the largest glacial boulder in the State.

At Independence are deposits of good potter's clay that were used many years ago. A pottery was in operation here in 1870–71, and one two miles north of town from 1855–65.*

The only exposure of Mansfield sandstone observed between Independence and little Pine creek is on the east side of a small tributary known as Dry branch. A coarse yellow sandstone of no commercial importance and containing patches of quartz conglomerate, forms a bold cliff along the east side of the ravine, the slope on the west side being covered with drift.

Little Pine Creek.—On Little Pine creek the yellow Mansfield sandstone outcrops through the northwest quarter of Sec. 17 (22 N., 6 W.), through Secs. 8 and 5 (22 N., 6 W.), and a small area of the red in Sec. 32 (23 N., 6 W.). The outcrop is observed to rest unconformably on the drab-colored shaly Riverside sandstone, which outcrops in a number of places. The outcrops show conspicuously in the bluff on the west side of the creek on the north side of Sec. 8 (22 N., 6 W.), where the relation of the shale and sandstone is as shown on the accompanying figure

*See Report on Clays by the State Geologist in this volume.

(Fig. 6), the underlying drab shale having been eroded before the overlying sandstone was deposited on the irregular surface.

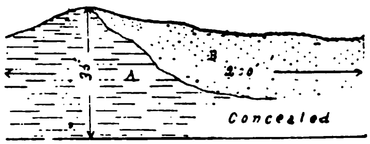


Fig. 6. Section on Little Pine Creek showing unconformity between the Lower and Upper Carboniferous rocks.

A—Lower Carboniferous (Riverside).
B—Upper Carboniferous (Mansfield).

At "Falling Rock" in the southeast quarter of Sec. 5 (22 N., 6 W.) is a bold outcrop of the sandstone in a small ravine where the sandstone 30 feet in thickness forms a perpendicular bluff which is kept so by the more rapid disintegration of the underlying shale and softer sandstone at the base of the deposit. The stream washing this away more rapidly in its channel than elsewhere gives the bluff its crescent shape. There are numerous occurrences similar to this throughout the sandstone area. A very similar one and one given the same name ("Falling Rock") occurs about two miles northeast in the northeast corner of Sec. 4 (22 N., 6 W.). Small quantities of medium quality yellow and gray sandstone have been quarried for local use on the slope north of Falling Rock in the southwest quarter of Sec. 5 (22 N., 6 W.) and other ledges equally as good occur in the northwest quarter of the same section.

Greenhill Red Sandstone Quarry.—Probably the most important sandstone from a commercial standpoint in this part of the county is the red sandstone in the west part of Sec. 32 and the east side of Sec. 31 (23 N., 6 W.). The stone outcrops along the south side of a small branch from the west, and so far as known is not exposed on the north side of the branch, the slopes being covered with glacial material. The stone has been quarried for use in building and bridges; the principal quarry opening being on the east side of the road a short distance north of the half section corner between sections 31 and 32. The face of the quarry is 20 feet, the total thickness of the bed is not shown, but is not less than 30 feet and may be much more. There is a little shelly rock at the top, but in no place more than one or two feet and the overlying drift is very light, being from zero to two or three feet. The stone on the quarry face is somewhat friable, much more so than that in the natural exposures or in the bridge abutments where it has been used. It has a light red color, a much lighter, brighter, warmer red than any other red sandstone of the State. The lighter color is apparently due to the presence of less iron than in the brownstones rather than a different state of hydration, the brighter color being due probably to the absence of the hydrous oxide.

The small quantity of iron is shown both in the chemical analysis and in the microscopic examination. The percentage of iron is lower than that in any other sandstone of the State that has been analyzed (see final chapter for comparison).

Chemical Analysis of Greenhill Red Sandstone.

Digested in concentrated hydrochloric acid (HCl).

Residue (white) insoluble in HCl	98.73
Alumina (Al_2O_3)	.28
Iron Oxide (Fe_2O_3)	.36
Lime (CaO)	.03
Carbonic acid (CO_2) (by computation)	.02
Total	99.41

The stone is remarkable, not only for the low percentage of iron, but of the alumina and lime as well, the percentage of all the soluble material being less than one per cent., so that the question naturally arise whether there is sufficient cement to make the stone of any value. In favor of its strength might be stated (1) that the grains are closely interlocked and there is probably some silicious cement, as a fragment of the stone digested in dilute acid for several days, still retained much of its tenacity, and (2) the stone where it has been used shows an indurated surface much harder than the fresh stone, and this despite the fact that the stone was quarried by blasting with powder and dynamite. The Martindale house, about four miles southeast of Pine Village, was constructed of stone from this quarry more than 35 years ago.* It shows no effect of disintegration yet, in fact is not even discolored. Examination with the core drill is said to have been made by Chicago parties in this locality several years ago, but nothing definite about the results could be obtained. Despite the fact of the friability of the stone in the quarry and the low percentage of cement, the evidence from the weathered face and the use in buildings and bridges is sufficient to warrant further exploitation of this stone when transportation facilities are offered.

Black Rock and vicinity.—At Black Rock, in the southeast quarter of Sec. 9 (22 N., 6 W.), is an isolated outcrop of yellow Mansfield sandstone and conglomerate, capping a high promontory overlooking the Wabash river. A section at this point shows 30 feet of massive Mansfield sandstone underlain by 75 feet of Lower Carboniferous shaly sandstone, thus making the top of the sandstone 105 feet above the river.†

*The actual date could not be ascertained further than that it was long before the war.

†The old county map gives it 140 feet, but careful measurements made by the writer on two different days with a good aneroid showed only 105 feet.

The Mansfield stone lies unconformably on the underlying shaly sandstone as shown on the accompanying figure (Fig. 7) and 30 feet denotes the

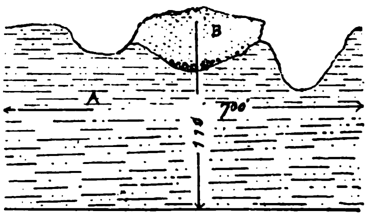


Fig. 7. Section of the bluff at Black Rock.

A—Riverside sandstone and shale.
B—Mansfield sandstone.

maximum thickness. The rock is very ferruginous and has little or no economic value. The conglomerate at the base contains pebbles of chert, quartz, and the underlying shaly sandstone. On top of this rock 50 to 75 yards back from the face of the cliff and 10 feet below the highest point is a chalybeate spring, which is heavily charged with iron and has formed a considerable deposit of iron oxide around it.

Sandstone and conglomerate outcrops at several places indicated on the map in the south part of Sec. 4 (22 N., 6 W.) and in the northeast corner of section 4 at "Falling Rock," but none of it has any value as a building stone. There is much conglomerate in this vicinity, and much of it is made up of geode fragments; in one place on a space of two or three square feet 24 geode fragments were counted. In some places the conglomerate is fine, the separate pebbles being about the size of wheat grains, while in other localities they are coarse, being about the size of hickory nuts. No Mansfield sandstone was observed east of the county line in Tippecanoe county, but the region was not explored and it is possible that small isolated spots of it may occur.

CHAPTER V.

NOTES ON THE SANDSTONE QUARRIES OF INDIANA, OUTSIDE OF THE AREA MAPPED.

The following notes are made from a more or less hasty examination of the different localities, and mainly on the commercial features of the stone with little reference to the stratigraphy, and are given here only as a preliminary report on these localities. Many of the quarries are more important commercially than many of those in the area mapped and are deserving of a more thorough investigation, in the absence of which these notes are given.

THE PORTLAND STONE, VERMILLION COUNTY, IND.

The Carboniferous sandstone quarried at Worthy, Vermillion county, is known in the market as Portland stone. The quarry is situated in a small ravine about 150 yards west of the main line of the C. & E. I. railway from Terre Haute to Chicago, on the west side of the Wabash river about four miles north of Hillsdale, in section 14 (Tp. 16, N. R., 9 W.)

The stone at the quarry of the Portland Stone Co. belongs to the age of the Coal Measures at a horizon above that of the Mansfield stone.* It is thought to be correlative with somewhat similar deposits of sandstone as yet undeveloped on the Little Vermillion river at Francis Davis' about three miles west of Newport, and on Big Vermillion river about six miles northwest of Cayuga, both in Vermillion county.†

Chemical Composition of the Portland Stone.—The following analysis of the Portland stone was taken from an article in the "National Builder," January 19, 1895, furnished by S. S. Gorby, State Geologist, but the analyst is not given nor any particulars in regard to the analysis:

Analysis of Portland Stone.

	Per cent
Silica ($Si O_2$)	91.182
Lime carbonate ($CaCO_3$)	.864
Magnesia (MgO)	1.413
Ferric oxide ($Fe_2 O_3$)	1.120
Alumina ($Al_2 O_3$)	2.134
Moisture and loss	3.287
Total	100.

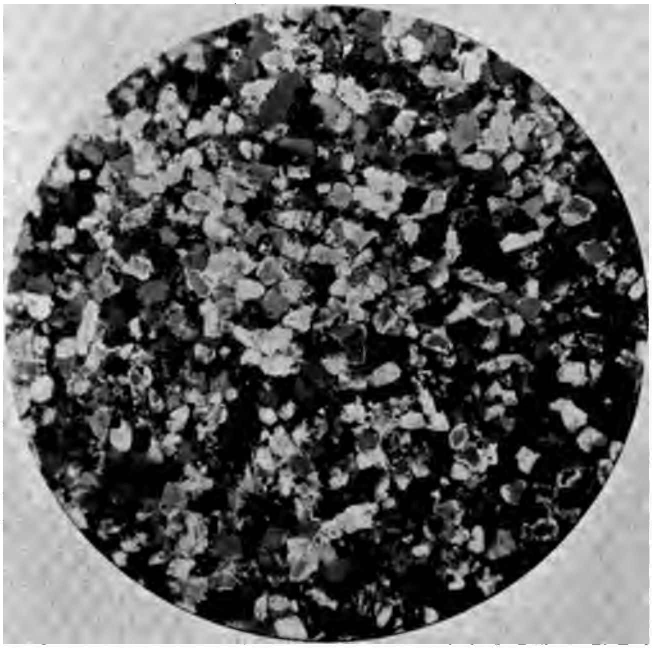
The crushing strength of Portland stone is given in the "National Builder" ‡ as 27,300 pounds per two inch cube, which would equal 6,825 pounds per square inch, providing it was a perfect two inch cube. This is about the average strength of good sandstones. See tables in final chapter of this report for comparison.

Microscopic and Mineralogic Character of the Portland (Ind.) Stone.—The Portland stone is finer grained and more complex in its mineralogic composition than the Mansfield stone. The stone contains about the same percentage of quartz as the Mansfield brownstone, but a lower percentage than the Mansfield gray or buff stone. The quartz is all angular

* Its more precise location in the Coal Measures, with its relation to the different coal beds, will no doubt be given in the economic report on the coal.

† Both these localities were visited and notes made on the outcrops and samples collected for examination, but lack of time has prevented laboratory examination and the preparation of the notes for publication.

‡ The "National Builder," January 19, 1895. The test was made by J. D. Kramer, Cincinnati, Ohio.



No. 1.

No. 2.

MICROPHOTOGRAPHS.

No. 1. CANNELTON SANDSTONE, CANNELTON, INDIANA.
No. 2. PORTLAND SANDSTONE, WORTHY, INDIANA.

as shown in the microphotograph, Fig. 2, Plate 15. The grains are comparatively uniform in size, averaging 0.214 millimeter or .0082 of an inch in diameter. The largest grain measured was 0.3 millimeter or .0118 inches in diameter. It will be noticed on comparison that in the size of the grains the stone resembles the buff colored Mansfield stone at Williamsport, and is finer grained than the brownstones. A few of the grains show they have been subject to strain, but the greater number of them are free from such appearance, so that while part of the grains may have come from an area of distorted strata much of it evidently did not. The grains are enclosed in a complex cement of clay, mica, granular and crystalline quartz, fragments of decaying feldspar, carbonates and iron oxide. The clay evidently comes, in part at least, from the decaying feldspar with which it is closely associated, along with granular quartz and calcite.

The mica is muscovite and occurs in small, ragged flakes, much of it intimately twisted among the grains, thus serving as an elastic bond of strength, and indicating a deposit simultaneous with the sand. The carbonates occur in minute, scattered, microscopic patches through the rock; they are thought to be in part calcite and in part dolomite, or siderite, or both. These minerals in minute quantities are not readily differentiated. The rock digested in cold dilute acid gave some effervescence, which, having ceased and the acid being heated, was renewed with even greater vigor than at first, thus indicating the occurrence of both the calcite and one or both of the other carbonates. The chemical analysis would indicate that all three might be present. The carbonates are unequally diffused through the rock, some areas being free from them, others containing not less than three or four per cent.

Some of the quartz grains are bound together by a quartz cement so firmly as to be differentiated only between crossed nicols. Whether the quartz has been deposited on the grains in their present position, or whether such areas are but fragments of quartzite from some other region does not in all cases appear. Yet the evidence appears to support the former view, as some of the areas are large enough to form a conglomerate if they were deposited as quartzite. In any case the quartz cement hardens and strengthens the rock.

The iron oxide occurs in very finely diffused grains that are possibly derived from oxidized iron pyrites or carbonate. None of the original sulphide was discovered, but not a sufficient number of fresh specimens were examined to prove its absence further than to prove that if it occurs, it is in minute quantities.

There is some finely diffused carbonaceous matter that aids in giving the deep bluish tint to the stone. In one place a fragment of fossil plant was found under the microscope that still retains its cellular structure.

The quartz grains contain some fluid inclusions and some microlites of zircon, apatite and rutile, but the inclusions are few and all minute.

The rock occurs in a massive bed, which in the quarry shows a working face of 51 feet, and it is said that a core from the diamond drill was taken out to the depth of 69 feet without reaching the bottom of the stone or a change in its character. However, the present face extends to the bottom of the ravine and to carry it any deeper would require pumping especially in wet weather. Should the stone prove to be of good quality to a considerable lower depth the pumping would not be a serious hindrance as there is no permanent stream in the ravine in dry seasons, and it could be done cheaper than to strip the overlying waste material On the present quarry face there is overlying the quarry stone a thickness of 25 feet or more of shale, fire-clay, coal and boulder clay. The fire-clay and coal are said to be utilized and probably more than pay for their removal. If the shale could also be utilized for paving brick it would add greatly to the profits of the quarry. Plate 16 shows a view of the quarry in operation.

The quarry was opened in 1894 by the Portland Stone Co., with offices at the quarry and in Chicago, and representing a capital of $40,000. The production of the quarry for the first year (1894) was 200,000 cu. ft.; for the past year (1895) 200,000 cu. ft.

The quarry is well equipped for work; the company employs from 30 to 60 men, and has besides its own railway engine for shifting cars, two steam power derricks, two horse derricks, three channelers (two in operation, 1895), one steam drill and two gangs of saws. They contemplate putting in a six gang mill.

The principal shipping points for the stone are Chicago, Ill., Milwaukee, Sheboygan, and Portage, Wisconsin; Detroit, Mich., and Terre Haute, Ind. Some stone has been shipped to each of the following points: Charleston, Homer, Muncie, Indianola, Rossville, Sadoris, Seymour, Danville and St. Joe, Ill.; Cayuga, Newport, Montezuma, and Dana, Ind.

Some of the stone is used for bridges and some for buildings. There are probably more than 200 buildings in Chicago which contain the Portland stone, either for entire fronts or as trimmings. Nearly all the brick houses and flats in Chicago have stone trimmings, such as cornices, lintels, water tables, etc., or else the entire front of stone and the side walls of brick. The Portland stone appears to give good satisfaction for such uses and is a growing rival of the Bedford and Joliet stone. The court house and church at Charleston, Ill., are built of Portland stone. It has had considerable use along the C. & E. I. railway for bridge stone, both on the main line and the C. & I. C. division. It was used in the bridge over the Calumet river in Chicago, built during the past summer, 1895.

The thickness of the deposit of the Portland stone, its massive structure, its homogeneity of texture, composition and color, the ease with

PORTLAND SANDSTONE QUARRY, WORTHY, INDIANA.

which it can be quarried and dressed, its location near the railway, its proximity to important markets, all combine to give it great commercial importance and the industry, which has so quickly risen to prominence, will no doubt continue to increase for some years to come, or until the expense of stripping the overlying waste material prohibits the further profitable production of the stone.

Clay County.

Brazil.—Sandstone has been quarried in limited quantities in several places in the vicinity of Brazil. The stone is of inferior quality and never had more than a local usage. The quarries are nearly all abandoned at the present time and will probably never again be worked to any extent, as the large brick works can supply a better and cheaper building material than can be obtained from the sandstone.

On the Pierce farm on the hill north of Newburg (Turner), two and a half miles west of Brazil, a soft, micaceous sandstone was quarried for foundation stone in Brazil. The quarry was in operation for ten or twelve years, but has been abandoned now for three or four years and the overlying soil and drift have crumbled in, almost entirely concealing the stone.

Stone has been quarried in small quantities at several localities along Otter creek, north of Brazil. At the high trestle on the C. & I. C. railway, stone has been quarried on each side of the creek. It is a very light gray sandstone, slightly variegated with yellow and more or less shelly on the exposed surfaces. It is both overlain and underlain by coal. Stone has been obtained here within the last two years, but the quarry is not now (1895) in operation.

On Otter creek in Sec. 18 (13 N., 6 W.), near the little town of Cardonia, gray, buff, and banded sandstone has been quarried for local use. The gray and yellow banded stone is very handsome in hand specimens, but is only of medium value for building material. The stone occurs in a bed 15 to 18 feet thick and has been quarried at several points along the Midland railway in this section. The sandstone at all the localities above mentioned in the vicinity of Brazil occurs in the Coal Measures at a higher horizon than the Mansfield sandstone.

Orange County.

Sandstone adapted for local use in foundations, bridges, curbing, etc., occurs in many places in Orange county. The best stone is that interstratified with the Lower Carboniferous limestones, and designated the Paoli sandstone by Mr. Kindle in his report on the whetstones of this region [See the following paper in this volume.]

Notes were made on the occurrence of this stone at several different localities, and samples taken, but lack of time has prevented an examination of the latter and a proper arrangement of the former. The stone has been quarried for local use at West Baden, Paoli, Orleans and elsewhere, and will no doubt be used more in the future than in the past when the people realize the ease with which it can be quarried and dressed. Here, as in most other limestone regions, the citizens have the impression that because it is much softer than limestone that it will not stand the weather.

The Mansfield sandstone of this region is for the most part too imperfect for good building stone, as it contains much conglomerate, cross-bedding and many iron secretions.

GREENE COUNTY.

Bloomfield.—A mile and a quarter northeast of Bloomfield in the southwest quarter of Sec. 13, (7 N., 5 W.,) is one of the most promising exposures of red or brown sandstone in the State of Indiana. It outcrops on each side of a small tributary of Richland creek, known locally as Warren branch, the largest and most promising exposure being on the west side. The thickness of the exposure is 35 feet, but as the bottom is concealed by the debris of the valley the total thickness of the deposit is unknown. The length of the exposure is about 200 yards, being concealed at each end by loose soil and debris. It occurs at the base of the hill which rises to a height of 50 feet or more but with a very gentle slope, and the stripping would probably not exceed 10 feet, 25 or 30 yards back from the face of the bluff.

The stone is remarkably uniform in texture and more uniform in color than is customary for the brownstone on the surface It is coarse to medium in grain as shown on the drawing (see No. 5, on plate 12) and weathers evenly, showing a firm, even, hard, indurated surface, in some places moss-grown. The base of the bluff is strewn with many large boulders, some 10 to 20 feet in diameter, some sharply angular and some rounded. Trees two feet or more in diameter are growing behind some of these boulders, indicating that they have been separated for many years from the parent ledge, yet as a rule there is but very little sand or debris about them, indicating that there has been very little disintegration; on the contrary they are harder on the surface than in the interior.

The stone varies in color, but is comparatively uniform at any one place. The prevailing color is reddish brown, somewhat brighter than the Connecticut brownstone and not unlike the stone at Mansfield and St. Anthony in color.

The chemical analysis shows it to have a high percentage of iron oxide, higher than most of the brownstone of Indiana. The microscope shows this iron to be partly crystalline, crystal faces measuring 0.032 millimeter in length occurring. The percentage of alumina and lime is remarkably low.

Chemical analysis of brownstone from Bloomfield.

	Per cent.
Residue (white) insoluble in hydrochloric acid	85.29
Ferric oxide (Fe_2O_3)	11.83
Alumina (Al_2O_3)	.19
Lime (Ca O)	.06
Carbonic acid (CO_2), (computed)	.05
Water and loss, by difference	2.58
Total	100.00

As shown by the microscope the insoluble residue is practically all quartz, the grains averaging 0.28 millimeter in diameter.

This stone has not been developed, not even for local use except a small quantity taken out this year (1895) by Mr. Joseph Shryer for the foundation of his house in Bloomfield, and that was taken from the loose boulders and not from the parent ledge. The location is in the little valley that leads to the Bedford–Switz City division of the Louisville & New Albany Railway about two miles distant, so the lack of transportation facilities ought not to be a serious drawback to the development of this stone.

Rockwood.—At Rockwood, about five miles south of east from Bloomfield, buff and gray sandstone has been quarried to some extent by Mr. J. Hassler and brother. The stone has been taken from two different openings. On the south side of Plummer creek, about a quarter of a mile south of the railroad, is a ledge of light gray sandstone, six to eight feet thick, that is an exceptionally fine building stone. It has such a smooth easy cleavage that it can be readily split in sizes of any dimensions. A slab twelve feet long, four feet wide and six inches thick, lying at the quarry, looks as regular as though it had come from the saw mill. The ease with which it can be quarried and its agreeable color should give this stone an extensive local use. It would make good whetstones or grindstones.

The stone at the railroad, on the north side of Plummer creek, near Mr. Hassler's house, is buff-colored and somewhat variegated in places. It is not as uniform, valuable, or desirable stone as that on the south side of the creek, yet is suitable for foundations and heavy masonry and has been quarried in considerable quantities.

DUBOIS COUNTY.

St. Anthony.—J. B. Lyne & Son operate a brownstone quarry about one mile west of St. Anthony, Dubois county, Indiana, near the middle of Sec. 27 (2 S., 4 W.). The quarry was opened in 1887 and operated on a small scale for two years when it was shut down. It was reopened in 1894 by Lyne & Son with improved machinery and is now doing an extensive business. They have built a switch from the quarry to the Louisville, Evansville & St. Louis ("Air Line") railway, and ship stone to Louisville, Evansville, St. Louis, Terre Haute and intermediate points.

The stone occurs in a massive bed varying from 10 to 16 feet in thickness. It is overlain and underlain by shale. The underlying shale is light gray with streaks of black, said to be accompanied by coal and fire-clay in places, but none is exposed at present. Near the north end of the quarry the shale is impregnated with considerable iron, which also occurs in small quantities in the base of the sandstone at this point. The overlying shale has a blue-gray color and contains some intercalary sandstone. One or two incipient bedding planes appear on the exposed surface of the sandstone, but disappear in the back part of the quarry. There are a few indistinct joint planes with a general east-west trend.

The chemical analysis of the stone shows it to have a lower percentage of silica and a higher per cent. of iron than the stone at Mansfield, closely resembling the Bloomfield stone in this respect.

*Analysis of St. Anthony Sandstone.**

	Per cent.
Residue (white) insoluble in concentrated HCl	88.41
Iron oxide (Fe_2O_3)	8.40
Alumina (Al_2O_3)	.63
Lime (CaO)	.13

The insoluble residue is practically all quartz as shown by microscopic examination. In the specimens examined the grains range in size from 0.09 mm. to 0.48 millimeters in diameter, the average of 20 contiguous grains being 0.32 mm. or 0.0126 inches. The quartz grains are angular, subangular and rounded and contain many fluid inclusions and a few microscopic apatite crystals. (See No. 4 on plate 12.) The only other mineral present in any appreciable quantity is the iron oxide, apparently a mixture of the red and brown hematites with probably a minute quantity of clay. See Chapter III, for physical tests on the St. Anthony stone.

The length of the quarry floor is about 800 feet. The stone has been stripped back from the face a distance of 10 to 30 feet, a small portion of

*See table in final chapter for comparison with other sandstones.

which has been removed and much of it channeled ready for removal. In most places two channel cuts of about six feet each are removed. The large area uncovered and the removal of the stone in large mill blocks in quantity enable the owners to select the colors in a more satisfactory way than can be done in a small quarry. Here as at Mansfield and elsewhere the stone is not uniform in color throughout. There are several distinct shades which, while partially grading into each other in places, can with care be separated by proper sawing of the stone, thus giving an opportunity to bring all the stone into groups of uniform color. As one shade may predominate more in one part of the quarry than in another, the advantage of having a large face to select from and a large stock in the yard will readily appear. The quarry is well equipped with channelers, drills, good derricks and a good mill, and apparently the only limit to the supply of good brownstone is when the expense of stripping the overlying shale and soil will prevent a profit on the stone. If arrangements can be made to utilize part or all of this now waste material for brick making or other purpose so as to wholly or in part pay for its removal this time may be indefinitely postponed.

Northwest of St. Anthony.—No other outcrops of brown stone are reported in the immediate vicinity of St. Anthony. A buff stone has been quarried near the town for use in building the Catholic Church and in some of the foundations. In the region west of north from the brownstone quarry the brownstone is said to outcrop at different points. The region was not traversed except the road from Jasper to Knoxville, along which the brownstone is exposed in a number of places. The largest and best exposures observed are at Herrman Brelage's, in sections 21 and 28 (1 S., 4 W.). The stone varies in color through several shades of brownish red, and in certain spots is impregnated with "iron blisters." At some of the exposures the color and texture are fairly uniform. How far the uniformity extends cannot be predicted definitely from the examination of the surface exposure. The largest single exposure observed was not more than twelve feet thick, but an outcrop eight feet thick near the top of the hill and another twelve feet thick at the base of the hill, thirty or forty feet below the first, would indicate that there is a bed of considerable thickness, possibly not less than forty feet. However, the intervening concealed interval may consist largely of buff sandstone or shale.

Jasper.—Gray and buff sandstone has been quarried for local use at several points in the immediate vicinity of Jasper. The Catholic Church at that place is constructed of stone from different quarries in the vicinity. The only quarry in operation in 1895 is operated by James Schroeder and one assistant, in the south part of Sec. 25 (1 S., 5 W.), a mile or more northeast of Jasper. The stone is gray and buff in color, and harder than the average Mansfield stone. The product is mainly used for foundations. Small quantities have been shipped to Huntingburgh for flagstone and curbstone. The Jacob Eckert quarry, on the east side of Patoka creek, about half a mile east of Jasper, has been abandoned for some years, as has the Fisher quarry, a mile north of the town.

PERRY COUNTY.

Cannelton.—Some of the largest and oldest sandstone quarries in Indiana are those near Cannelton, Perry county. Sandstone is exposed in the Ohio River bluffs in many places in Perry county, and has been quarried at and below Cannelton, but the most valuable stone, and that which has been quarried most extensively, occurs on the bluff two to four miles above (east of) Cannelton at and below Rock Island, in sections 12, 13, and 14 (7 S., 3 W.).

The Mansfield sandstone and conglomerate occurs at the base of the bluff at Rock Island, but is not quarried, except in small quantities for rip-rap. The dimension stone is all taken from the overlying Coal Measures. Part of the Mansfield formation is coarse conglomerate composed of pebbles a quarter to a half inch in diameter, in places the pebbles forming a closely compact mass, with little sand, in other places loosely scattered through the sandstone, and occasionally occuring in layers, following the false bedding of the stone.

The dimension stone has been taken from beds overlying the Mansfield stone, and in most places separated from it by a bed of black shale. It is finer grained than the average Mansfield sandstone, the average diameter of the grains being 0.14 millimeter, the largest being 0.2 mm. (See Nos. 1 on Plate 15 and 6 on Plate 12.) The chemical analysis shows a higher percentage of insoluble residue than the average sandstone, but this residue is not all quartz, as in much of the Mansfield stone, but mica, both muscovite and biotite, occurs; the quartz contains zircon, apatite and rutile crystals.

Chemical analysis of Cannelton Sandstone.

	Per cent.
Residue, insoluble in hydrochloric acid	96.18
Ferric oxide (Fe_2O_3)	1.56
Alumina (Al_2O_3)	.54
Lime (CaO)	.15
Total	98.43

The color varies from a lemon-yellow to a light or dark gray. In general, however, the color is comparatively uniform at any one quarry opening, varying from place to place. The color is in no place an attractive one for fine buildings, owing to the rusty yellow tint of the iron oxide that always occurs. It is better adapted to heavy masonry, where eauty is subordinated to ease of working and durability.

The stone occurs in a massive bed, which only rarely shows open bedding planes, but nearly always has an easy cleavage parallel to the bedding, so that it can be readily split into any thickness desired. This greatly facilitates the working of the stone, which is all done by hand. A channeler was used for a while in one of the quarries, but is idle at present (1895), the apparent reason for its idleness being that the stone at the point where it has been used is of inferior quality. In many of the openings there is not sufficient quarry floor to use a channeler to advantage. The stone occurs on the face of a steep bluff and is overlain by black shale, overlain in turn by other sandstone. The stone is quarried back in the bluff until the thickness of the overlying shale becomes too great to remove and permit any profit on the stone.

As the shale is not, in physical appearance at least, unlike that used elsewhere for paving bricks, it is possible that it might be so used here. The appearance of the shale is sufficient at least to warrant an investigation in that line. In some places it would be possible to run an incline track or chute from the shale bed to the river bank, and the loading of it on barges would be a slight expense. Even though it would but partially pay for its removal it would uncover large quantities of valuable stone, the profits on which would help pay for removal of the shale.

The large cotton mill and the Catholic church at Cannelton, are constructed of stone from these quarries. There are a dozen or more smaller buildings in Cannelton, store rooms, dwelling houses, etc., which are built of it; also many foundations, retaining walls, etc. It was used in the locks on the canal at Louisville, Ky., and for a similar purpose on the Green river, Ky. It has been used in a number of places along the Ohio river for rip-rap, retaining walls, wharves, etc.; some shipped as far down as Memphis.

The quarrying of sandstone at this locality will no doubt prove to be an important industry for many years to come, as the stone occurs in a heavy deposit, easily worked, and well adapted to heavy masonry.

CHAPTER VI.

SUMMARY.

The investigation shows that sandstone of good quality and in commercial quantities occurs at several different horizons in the Carboniferous system in western Indiana. It also shows that along with the good stone in each of these beds there is much that is inferior and that care is necessary in selecting the product. In the chapter on local details, as far as possible, all the points where good stone for local use occurs are designated, and in a less degree the defective stone is described and the defects pointed out, that it may be avoided.

The most important bed of sandstone is that termed the Mansfield, which lies at the base of the Coal Measures, unconformably on the Lower Carboniferous limestones, and is supposed to be the equivalent of the Millstone grit of adjoining States and extends in a strip varying from two to ten miles or more in width, from the north part of Warren county in an east of south direction to and beyond the Ohio river, a distance of more than 175 miles in the State of Indiana. Over all the north part of this area, all that is shown on the two accompanying map sheets, is a belt of glacial drift material, varying in thickness from zero to 200 feet or more. The great mass, probably nine-tenths, of the formation is made up of a medium to coarse-grained massive sandstone, which is associated with (1) patches of conglomerate, varying from a few inches to several feet in thickness and from a few feet to hundreds of yards in lateral extent, (2) shaly sandstone, (3) shale, (4) coal and (5) fire-clay.

The source of part of the coarse material of the conglomerates and the sandstone is shown to be from the cherts and geodes of the underlying limestones. The remainder is probably from the crystalline areas of the lake regions.

While the Mansfield sandstone is soft, friable, and easily worked, it is at the same time one of the most durable rocks in the State. This is proven by its topographic features and its use in buildings and bridges. It consists essentially of quartz grains in a cement of iron oxide, with some silica and minute quantities of clay; it is locally micaceous and contains small quantities of feldspar and other minerals in places. The tendency of the iron oxide to segregate injures much otherwise good stone. The grains are mostly angular, but in the coarser varieties some of them are rounded and subangular.

The many varieties in color are grouped under the two general heads of: (1) Brownstone, including the red-brown, purplish-brown and chocolate-brown, and (2) buff and gray stone, variegated stone, occurring in each class. Commercial stone is obtained in both classes, but is less abundant and more valuable in the first than in the second class.

The greatest drawbacks to the more rapid development of this stone are: (1) The absence of railway facilities at some of the best deposits; (2) the occurrence of the so-called iron "blisters" or "kidneys" that injure the brownstone in many localities; (3) the presence of much cross-grain or false-bedding; (4) lack of uniformity in color; (5) inferior stone having been quarried and put on the market, thus injuring the reputation of the good stone. Throughout a large portion of the area much of the stone is injured by one or more of these causes, yet in many places the stone is so far free from these defects that it could be worked with profit as is done in a few places. The stone is deserving of a more extended use than it has at present, yet the poorer stone that will be put on the market from time to time by careless quarrymen will always be a drawback to the development of the stone.

Quarries in the Mansfield stone are in active operation at St. Anthony (brownstone), Williamsport (buff), Attica and Kickapoo (buff), Fountain (brown and buff), and numerous small quarries throughout the area. One brownstone quarry has been opened this year (1895) at Portland Mills. There are idle quarries at Mansfield, Hillsboro, Attica, Greenhill and elsewhere throughout the area. Undeveloped deposits occur at different points, the most promising being in Parke and Greene counties.

Sandstones in the Coal Measures.—Interstratified with beds of coal and shale, sandstone of good quality occurs in a number of places in the Coal Measures at a horizon above that of the Mansfield stone. These were not examined in detail, but notes made at a number of different points show much valuable stone.

The so-called Portland stone at Worthy, Vermillion county, is one of the best building stones of the State and is taken from one of the most productive quarries. The stone has a gray-blue color varying to light buff near the surface. It occurs in a massive bed more than fifty feet in thickness overlain by shale coal and glacial drift. It is highly silicious, consisting largely of quartz grains in a complex cement of clay, silica, and iron and lime carbonates. It is not so durable as the Mansfield stone, but judging from the outcrop and the composition it is equal to the average in this respect.

At Cannelton, on the Ohio river, are extensive quarries of Carboniferous sandstone immediately overlying the Mansfield stone. It is not so attractive in color as the Portland stone and will not command as high a price for building purposes, but it is accessible in larger quantities, is equally as durable, possibly more so, is easily worked and is well adapted to use in heavy masonry. These quarries have been productive for many years.

Sandstone of Carboniferous age has been quarried at Jasper, Brazil, Coxville, and points west of Newport, northwest and northeast of Cayuga, south and west of Covington, and elsewhere.

Riverside Sandstone.—At Riverside, Fountain county, are two large quarries (one in operation in 1895) in sandstone of Lower Carboniferous age. The stone varies from a light blue color on the interior to a drab or buff on the exterior. It is evenly stratified in layers from two inches to more than three feet in thickness, the thinner layers being on the exterior, and the thicker ones in the interior. It is very fine grained, takes a smooth finish and is adapted to delicate carving and ornamentation. It is not so highly silicious as the sandstones of the Coal Measures, and has a greater variety of mineral constituents. While the Riverside sandstone is not so durable as the Mansfield stone and not so well adapted to heavy masonry, yet it is better adapted to trimming or carved work. The bulk of the stone is used at Lafayette and neighboring towns, yet some of it has been shipped to more distant points.

Similar stone to that at Riverside has been quarried near Attica at Raccoon Station on the I., D. & W. railway and on Big Walnut creek east of Bainbridge, Putnam county, and other points in the State.

In the southern part of the area there are at least two beds of sandstone in the Lower Carboniferous limestones, a much coarser grained stone than the Riverside stone, and resembling the buff-colored Mansfield stone. It is thought to occur at a horizon between the Riverside and the Mansfield (the Chester?). It has been quarried for local use at several places in Orange county.

The crushing tests of the Indiana sandstones indicate a stone about equal in strength to stones of similar character elsewhere, but below the average for all sandstones if the quartzitic varieties are included. The fire tests would indicate a stone that would not stand a fierce conflagration without more or less serious injury. However, the reports from its use in fire places, chimneys, sugar furnaces, and blast furnaces indicate a fire-resisting stone of some merit, from certain localities at least.

The experimental and statistical information is tabulated in the following pages. The value of the annual production varies from $80,000 to nearly $200,000.

TABLE I.

Statistics of sandstone production in Indiana for 1891, 1894 and 1895.

Location of quarry.	Kind of stone.	Capital invested.	1891.		1894.		1895.	
			Cu. Ft.	Value.	Cu. Ft.	Value.	Cu. Ft.	Value.
Williamsport	Buff.	$25,000	105,000	$10,500	210,000	$23,000	200,000	$22,000
Kickapoo	Buff.	....	....	....	35,000	2,000	40,500	2,100
Attica	Buff and Drab.	....	231,600	23,160	61,000	6,100	60,000	6,000
Riverside	Blue and Gray.	19,000	128,000	34,400	67,500	9,500	81,000	12,000
Worthy	Gray.	50,000	(1)	(1)	200,000	20,000	200,000	20,000
Cannelton	Buff.	5,000	61,000	6,100	54,000	12,000	283,000	38,000
St. Anthony	Brown.	30,000	(1)	(1)	12,000	5,000	50,000	15,000
Jasper	Buff.	3,500	13,500	1,755	1,500	200	1,500	200
Silverwood	Blue and Gray.	250,000	206,250	57,750	(1)	(1)	(1)	(1)
Mansfield	Brown.	150,000	41,250	30,100	(1)	....	(1)	....
Other Points	Brown, Buff and Gray.	77,000	77,400	5,600	20,000	2,000	25,000	2,500
Total		$609,500	864,000	$169,365	661,000	$79,800	1,140,000	$117,800

(1) Not in operation.

At Riverside in 1891 there were two quarries in operation; in 1894 and 1895 there was only one.

A rough estimate, based on the dimensions of the different quarry openings throughout the area traversed, shows a total production of about 3,750,000 cubic feet, of which 2,000,000 feet would come from the Wabash valley above Coal creek. This estimate includes the product for local use from the many small quarries. It is possibly far within the limit of the actual output.

TABLE II.

General statistics of the sandstone industry in Indiana in the years 1891, 1894, 1895.

ITEM.	1891.	1894.	1895.
Whole number of men employed	307	410	414
Average wages	$1.50	$1.75	$1.75
Number of quarries in operation	21	13	15
Number of derricks	40	36	46
Number of steam drills	9	6	7
Number of channeling machines	10	5	5
Number of saw gangs	3	4	6
Average price per cu. ft	$0.20	$0.14	$0.14
Highest price per cu. ft	73	65	60
Lowest price per cu. ft	10	4	4

TABLE III.

*Statistics of the Sandstone Production in 1891 **

Number.	Locality.	Number of quarries.	Capital invested.	Number of employees.	Average wages.	Number of cubic feet.	Price per cubic foot.	Number of steam drills.	Number of channelers.	Number of derricks.	Number of saw gangs.	Value of product.
1	St. Anthony	2	$5,000	....	....	....	....	1	....	....	....	†
2	Jasper	2	3,500	7	$1.50	13,500	$0.13	....	....	2	....	$1,755
3	Cannelton	3	2,400	58	{ 1.35 / 2.25 }	61,000	10	....	....	9	....	6,100
4	Fountain	1	300	3	1.25	5,400	11	....	....	....	....	600
5	Silverwood	1	259,000	60	1.50	206,250	28	....	4	....	3	57,750
6	Pottsville	1	1,500	12	1.25	72,000	7	....	....	....	....	5,000
7	Mansfield	1	150,000	20	1.50	41,250	73	....	2	3	....	30,100
8	Attica	2	40,500	39	1.50	231,600	10	....	....	7	....	23,160
9	Williamsport	6	6,000	73	{ 1.25 / 1.50 }	105,000	10	....	....	13	....	10,500
10	Riverside	2	15,000	35	{ 1.50 / 1.75 }	{ 20,000 / 108,000 }	{ 10 / 30 }	8	4	6	....	34,400
	Totals	21	$523,900	307	$1.50	864,000	$0.20	9	10	40	3	$169,365

* Collected and tabulated from the report by Mr. A. C. Benedict to the State Geologist, and published in the Seventeenth Annual Report of the State Geologist of Indiana, 1891.

† Not in operation in 1891.

Sandstone product in Indiana for 1889.—The sandstone product for 1889, valued at $43,983, is as follows: Warren county, $19,163; Fountain county, $14,500; smaller amounts in Orange and Putnam counties, in all 11 quarries. Of the total, the amount of $16,033 was used for building purposes, $18,080 for bridge work, etc. All of Orange county's product was used for abrasives.—*Mineral resources of the United States*, 1889-90, p. 393.

List of companies and individuals operating sandstone quarries in Indiana, with dates.

1. Williamsport Stone Co., Williamsport; quarry opened in 1840; worked by the present company since 1893.
2. F. J. Bernhart, Attica; since 1892 run by F. J. Bernhart; quarry first opened by his father in 1856.
3. Jacob Schmidt, Attica; since 1892; operated other small quarries in previous years.
4. Guyer, Burchby & Co., Riverside; since 1887. Riverside Stone Co. has a quarry close by the above, opened many years previous, but not in operation in 1895.
5. J. B. Lyne & Son, St. Anthony; since 1894; first opened in 1887.
6. F. F Paulin & Co., Cannelton; since 1884; first opened at Cannelton, many years previous.
7. American Cannel Coal Co., Cannelton; since 1895.
8. Parke County Brownstone Co., Mansfield; from 1891 to 1894; now in the hands of receiver; operated by M. W. Wolf, 1887-1891.
9. Portland Stone Co., Worthy; date of opening not at hand, but only a few years ago; has been in vigorous operation ever since.
10. Joseph Marlowe, operating Indiana Greenstone quarry at Kickapoo, near Attica, since 1892; quarry was opened many years previously.
11. Charles A. House, Rainsville, has operated small quarries for local use for several years.
12. Louis F. Inglehart, Harmony, with his father has operated a small quarry for 30 years.
13. John Jones, Paoli, has operated local quarries since 1885.
14. Hamilton Tigert has operated small quarry since 1892.
15. Portland Mills Brownstone Company opened a large quarry at Portland Mills in 1895.
16. Hillsboro Brownstone Co. and L. K. Stevens operated brownstone quarries at Hillsboro for several years; only small quarries for local use in operation in 1895. The Stevens quarry now owned by C. W. Moore.
17. Mr. Brooks, at Fountain, operates a small quarry for local demand.

18. J. Hassler has operated quarries in gray and buff stone at different times at Rockwood, near Bloomfield, Greene county.

19. Jas. Schroeder has operated a small quarry near Jasper since 1887. Other quarries, known as the Eckert quarry and the Fisher quarry, have been worked until recently in the same locality.

Quarries were opened this year (1895) by the Condon Bros., at English, in Crawford county; others at West Baden, Orange county.

There are a number of quarries that were at one time large producers, but are now idle, the largest of such being owned by the Cayuga Pressed Brick and Coal mining Co., near Silverwood, that was in operation from 1888 to 1892 and shipped between 3,000 and 4,000 carloads of stone. Smaller quarries now idle are those near Covington, Coxville and Brazil.

TABLE IV.

Value of sandstone production in the United States, by States, from 1890 to 1894 *

STATES.	1890.	1891.	1892.	1893.	1894.
Alabama	$43,965	$30,000	$32,000	$5,400	$18,100
Arizona	9,146	1,000	35,000	46,400	....
Arkansas	25,074	20,000	18,000	3,292	2,365
California	175,598	100,000	50,000	26,314	10,087
Colorado	1,224,098	750,000	550,000	126,077	69,105
Connecticut	920,061	750,000	650,000	570,346	322,934
Florida	(a)	....	....	....	....
Georgia	(a)	....	2,000	....	11,300
Idaho	2,490	....	3,000	2,005	10,529
Illinois	17,896	10,000	7,500	16,859	10,732
Indiana	43,983	90,000	80,000	20,000	22,120
Iowa	80,251	50,000	25,000	18,347	11,639
Kansas	149,289	80,000	70,000	24,761	30,265
Kentucky	117,940	80,000	65,000	18,000	27,868
Maryland	10,605	10,000	5,000	360	3,450
Massachusetts	649,097	400,000	400,000	223,348	150,231
Michigan	246,570	275,000	500,000	75,547	34,066
Minnesota	131,979	290,000	175,000	80,296	8,415
Missouri	155,557	100,000	125,000	75,701	131,687
Montana	31,648	35,000	35,000	42,300	16,500
Nevada	(a)	....	....	....	....
New Hampshire	3,750	....	....	....	....
New Jersey	597,309	400,000	350,000	267,514	217,941
New Mexico	186,804	50,000	20,000	4,922	300
New York	702,419	500,000	450,000	415,318	450,992
North Carolina	12,000	15,000	....	....	....
Ohio	3,046,656	3,200,000	3,300,000	2,201,932	1,777,034
Oregon	8,424	....	35,000	....	....
Pennsylvania	1,609,159	750,000	650,000	622,552	349,787
Rhode Island	(a)	....	....	....	....
South Dakota	93,570	25,000	20,000	36,165	9,000
Tennessee	2,722	....	....	....	....
Texas	14,651	6,000	48,000	77,675	62,350
Utah	48,306	36,000	40,000	136,462	15,428
Vermont	(a)	....	....	....	....
Virginia	11,500	40,000	....	3,830	2,258
Washington	75,936	75,000	75,000	15,000	6,611
West Virginia	140,687	90,000	85,000	46,135	63,865
Wisconsin	183,958	417,000	400,000	92,193	94,888
Wyoming	16,760	25,000	15,000	100	4,000
Total	$14,464,095	$8,700,000	$8,265,500	$5,195,151	$3,945,847

(a) Sandstone valued at $26,199 was produced by Rhode Island, Nevada, Vermont, Florida and Georgia together, and this sum is included in the total.

* From Mineral Resources of the United States, Part IV, 16th An. Rep. U. S. G. S., 1894.

TABLE V.

*Value of different kinds of stone produced in the United States during the years 1893 and 1894.**

KINDS.	1893.	1894.
Sandstone	$5,195,151	$3,945,847
Granite	8,808,934	10,029,156
Marble	2,411,092	3,199,585
Slate	2,523,173	2,790,324
Limestone	13,947,223	16,512,904
Bluestone	*a*1,000,000	*a*900,000
Total	$33,885,573	$37,377,816

* Mineral Resources of the United States. Part IV., 16th An. Rep. U. S. G. S., 1894.

a Estimated.

TABLE VI.

Table showing chemical composition of sandstones.

Number.	Locality	Insoluble residue.	Alumina.	Iron oxide.	Lime.	Magnesia.	Water and loss.	Total.
1	Mansfield	92.16	....	6.29	.05	....	....	*98.59
2	Judson	93.21	.51	4.91	.12	....	....	98.75
3	Hillsboro	91.65	.56	6.60	.12	....	....	98.93
4	Fountain	91.66	.60	6.41	.05	....	....	98.72
5	Bloomfield	85.29	.19	11.83	.06	....	....	97.43
6	St. Anthony	88.41	.63	8.40	.13	....	....	97.57
7	Riverside	93.16	1.60	2.69	.13	....	....	97.58
8	Williamsport	98.57	.05	.65	.02	....	....	99.29
9	Greenhill	98.73	.28	.36	.03	....	....	99.40
10	Cannelton	96.18	.54	1.56	.15	....	....	98.43
11	Worthy (Portland Stone)	91.18	2.13	1.12	.86	1.41	3.29	100.00
12	Fern	....	.47	1.43	....	tr.	....	....
13	Portland Mills	....	2.87	19.34	....	tr.	....	....
14	Portland, Conn	69.94	13.15	2.48	3.09	tr.	1.01	†100.00
15	Dakota, Minn	81.55	10.00	1.41	1.15	0.30	....	100.00
16	Waverly, Ohio	91.00	5.20	1.47	tr.	0.28	1.80	100.00
17	Cleveland, Ohio	91.67	6.92	tr.	0.28	0.34	1.17	100.00
18	Cromwell, Conn	70.84	13.15	2.48	3.09	tr.	1.01	‡100.00

* Includes .09 per cent. alkalies.

† Includes 3.3 per cent. potash, 5.43 per cent. soda, and .7 per cent. manganese oxide.

‡ Includes 1.76 per cent. potash, 1.03 per cent. soda.

Nos. 1 to 10 analyzed for the survey by H. H. Ballard, Rose Polytechnic Institute, Terre Haute, Indiana. No. 11, from the "National Builder," January 19, 1895, by S. S. Gorby. Nos. 12 and 13, made for the survey by Dr. P. S. Baker, De Pauw University. Nos. 14 to 17, from Stones for Building and Decoration, by G. P. Merrill, p. 420. No. 18, furnished by the New England Brownstone Co. In Nos. 14 to 18 the insoluble residue is silica.

TABLE VII.

Table showing specific gravity, crushing strength and ratio of absorption of sandstones.

Number	Locality.	Specific gravity.	Weight per cubic foot.	Ratio of absorption.	Crushing strength per square inch.
			Pounds.		Pounds.
1	St. Anthony, Ind.	....	....	3/40	3,000
2	Riverside, Ind	....	....	3/50	6,045
3	Riverside, Ind	....	....	1/25	6,100
4	Riverside, Ind	....	....	3/80	6,800
5	Worthy, Ind	....	....	....	6,825
6	Berea, Ohio	2.11	132	1/70	11,213
7	Hummelstown, Pa.	....	....	....	12,810
8	Cromwell, Conn	2.5	156	1/40	16,894
9	Middletown, Conn	2.36	149	1/70	6,950
10	Gunnison, Col	2.20	137.49	.09	5,250
11	Coal Creek Col	2.03	126.82	.167	2,879
12	Portland, Conn	....	....	....	4,945
13	Marquette, Mich.	2.29	142.8	1/12	6,165
14	Jordan, Minn	1.90	118.9	1/8	4,750
15	Medina, N. Y.	2.41	150.6	1/53	17,250
16	Cleveland, Ohio	2.24	140	1/37	6,800
17	N. Amherst, Ohio	2.14	133.7	1/15	5,450
18	Angel Island, Cal	2.73	170.6	1/31	4,574
19	San Jose, Cal.	2.64	165	1/18	2,400
20	Bass Island, Wis.	2.04	127.5	1/18	4,850

NOTE.—Tests on Nos. 1 to 4 made for the Survey by M. A. Howe, Rose Polytechnic Institute, Terre Haute, Indiana. No. 5 from the National Builder, Jan. 1, 1895, by S. S. Gorby. No. 6 made by Mr. Howe at Terre Haute. Tests on the same given by G. P. Merrill, Building and Ornamental Stones equal 10,250 and 8,222.

BIBLIOGRAPHY.

The following bibliography does not aim at completeness, but as it contains probably the references to the most important literature on the subject it may be of value to those desirous of looking up the subject further. Very little has been written on the sandstones of Indiana, outside of a casual mention of their occurrence in the different county reports on the counties in the Carboniferous area.

SANDSTONES OF INDIANA.

BENEDICT, A. C. Quarries in Indiana, in 17th Annual Report Department of Geology and Natural Resources of Indiana, 1891, pages 106-113, gives statistics of the sandstone quarries in 1891.

COLLETT, JOHN. (1.) Geology of Dubois county in 3d and 4th Annual Report Geological Survey of Indiana, 1872, page 236.

(2.) Same volume, page 298, says the sandrock near the county seat of Jasper county is of excellent quality, equal to any in the State for foundations and heavy masonry.

(3) Geology of Warren county, pages 191–246 in the 5th Annual Report Geological Survey of Indiana, Indianapolis, 1874, in several places calls attention to the sandstone in the county as suitable for building stone.

(4.) Geology of Lawrence county, same volume, pages 260–314, mentions the sandstone of that county as weather and fire-proof sandstone.

COX, E. T. (1.) 2d Geological Report of the Geological Survey of Indiana made during the year 1870; Indianapolis, 1871, page 77, the massive sandstone in the hills north of Washington in Daviess county will make a durable building stone. Pages 82 and 105, the conglomerate sandstone occurs in large quantities, and where free from iron and pebbles is a handsome and durable stone. Pages 119 and 120, mention the occurrence of sandstone in western Indiana. On pages 204 and 205 he describes the sandstone and conglomerates of Dubois county, saying they are fire-proof.

(2.) 3d and 4th Annual Reports of Geological Survey of Indiana, Indianapolis, 1872, pages 83 and 138, mentions the sandstone on the bluffs at and above Cannelton as excellent building stone, enumerates the buildings and government works in which it was used.

(3.) Geology of Pike County, in same volume. Page 284 states that the "massive member of the subcarboniferous sandstone" about Pikesville furnishes the best quality of building stone; also that good Coal Measures sandstone occurs in other parts of the county.

HOBBS, B. C. Geological Survey of Parke County in 3d and 4th Annual Reports Geological survey of Indiana; Indianapolis, 1872. Pages 341–384 calls attention in several places to the heavy beds of sandstone in the county and gives vertical sections.

MINERAL RESOURCES, U. S. 1887, page 729. Chester sandstone (Subcarboniferous), well developed in Warren county and thence in a belt traceable to the Ohio river. Quarries at Williamsport and Attica, Warren county; near Attica and Portland, Fountain county; French Lick and Paoli, Orange county; and 7 N. and 6 N. 4 W., Greene county. Some of the quarries actively worked and furnish large amounts of stone.

Same as above in Mineral Resources 1882, page 680.

Statistics of sandstone production in Indiana, in volume for 1889 and 1890, p. 393.

OWEN, RICHARD, in report of a geological reconnoissance of Indiana made during the years 1859 and 1860, under direction of David Dale Owen, Indianapolis, 1862, pages 164 and 165, speaks of the sandstones of Warren county and Fountain county, calls attention to the coarse sandstone (Mansfield) and the Lower Carboniferous (Riverside), which are quarried between Attica and Williamsport; makes mention of the stone quarries east of Attica, now abandoned, but did not visit the quarries. Page 180: "The eastern portion of Dubois county furnishes sandstone for building purposes from the Millstone grit." Page 183: "Near Cannelton, as well as in other parts of the field, sandstone is quarried for building purposes." Also makes some general remarks on the properties of sandstones.

THOMPSON, MAURICE. Indiana sandstone, in 17th Annual Report of Department of Geology and Natural Resources of Indiana, 1891, pages 30–40, gives in outline descriptions of some of the sandstones and the counties in which they occur.

SANDSTONES IN GENERAL.

BECKER, G. F. Monograph XIII, U. S. Geological Survey; origin of concretions, weathering, alteration, etc., of sandstones.

CHAMBERLIN, T. C. Geology of Wisconsin, volumes I and II, Madison, 1883. Treats briefly of sandstones in general and more in detail the sandstones of Wisconsin from both an economic and scientific standpoint.

DANA, JAS. D. Manual of Mineralogy and Lithology, pages 426, 427. J. Wiley & Sons, New York, 1884.

DAY, WM. C. The Sandstone Industry in 1894. Extract from 16th Annual Report of the Director of the U. S. Geological Survey, Part IV, pages 55–65. Washington, 1895.

GEIKIE, A. Text-Book of Geology, pages 161, etc. Macmillan & Co., 1885.

HAWES, G. W. Geology of New Hampshire, volume III, 1878, part 10, page 240, also in 10th Census, vol. X.

HULL, EDWARD. Pages 237 to 279 in A Treatise on the Building and Ornamental Stones of Great Britain and Foreign Countries. Macmillan & Co., London, 1872. Gives a short general treatise on sandstone and a description of the sandstone of England, Scotland, Ireland, India and the continent.

IRVING, R. D. Geology of Wisconsin, volumes I and III. Treats in detail the sandstone of Wisconsin and less specifically sandstones in general, microscopic examination, chemical analyses.

IRVING, R. D., and VAN HISE, C. R. Bulletin 8, United States Geological Survey, Induration of Sandstone; illustrated. Shows that quartzitic and other crystalline sandstone may be produced by deposition of silica on sand grains oriented crystallographically with the original grains.

JONES, DAVID P. *Flagstone*, in the Mineral Industry, volume III, 1894, pages 495–504. Scientific Publishing Co., New York, 1895. Describes the North river bluestone, Colorado red flagstones and Kansas flagstones.

KELLY, THOS. C., *et al.* Sandstones, 10th Census, 1880; volume X, pages 25–27.

MAW, GEORGE. On the disposition of iron in variegated strata, in Quarterly Journal Geological Society, volume XXIV, 1868, pages 351–400. Gives a careful, detailed account of the nature, character, origin, etc , of the iron coloring matter in sandstone and other rocks.

MERRILL, F. J. H. Building stones of New York, In the Mineral Industry, volume III, 1894, pages 493–4. Scientific Publishing Co., New York, 1895.

MERRILL, G. P. Stones for Building and Decoration, pages 245–290. J. Wiley & Sons, New York, 1891. Also in Smithsonian Report for 1886, part II.

PAGE, DAVID. Economic Geology, pages 66–72. Treats of sandstones from an economic standpoint.

ROTH, J. Allgemeine und Chemische Geologie, volume II, page 607, *et seq.*

RUSSELL, I. C. Bulletin 52, U. S. G. S. on the origin of the red color in the Triassic sandstone of the Eastern States.

SEELEY, H. G. In Phillips' Manual of Geology, London, 1885, part I, pages 92–98. Microscopic character of sandstones of England and general character of sandstone.

SMOCK, JOHN C. In Bulletin of the New York State Museum, volume II, No. 10; September, 1890. Building Stones in New York, Albany, 1890. Brief general treatise on sandstone and description of the sandstone of different geologic ages in New York, and description of the different quarry regions; also treats of the durability of sandstone in New York City; pages 214–227, 255–281, 294–304. Also in Bulletin No. 3, 1888; pages 14–19, 49–93.

SPERR, F. W., *et al.* Sandstones, 10th census, 1880; volume X.

WINCHELL, N. H. Building Stones, in the Geology of Minnesota, volume I, of the final report, pages 176–182; Minneapolis, 1884. Describes the sandstones of Minnesota, gives chemical analyses, physical tests, etc., and illustrated by microscopic sections.

ZIRKEL, DR. FERDINAND. Lehrbuch der Petrographie, 2d edition, volume III; pages 715–744. Verlag von Wilhelm Engelmann, 1894. Probably the best scientific treatise on sandstones, especially on European stones.

CORNELL UNIVERSITY,
ITHACA, N. Y., Jan. 10, 1896.

Prof. W. S. Blatchley, State Geologist:

DEAR SIR—I have the honor to transmit herewith a report of my work during the past field season.

Respectfully,

E. M. KINDLE,
Assistant Geologist.

THE WHETSTONE AND GRINDSTONE ROCKS OF INDIANA.

BY EDWARD M. KINDLE.

CHAPTER I.

TOPOGRAPHY AND GENERAL GEOLOGY.

POSITION.—The sandstones which supply the coarse and fine grained whetstones and the grindstones of Indiana, are confined principally to the western half of Orange County. The territory which has been mapped during the study of these beds embraces the western part of Orange, the southeastern portion of Martin, and the northeastern part of Dubois counties lying between the second principal meridian and range line four west, and extending from the northern to the southern boundary lines of Orange County.

TOPOGRAPHY.—This region lies south of the southern limit of the drift, and presents a variety of topography very different from that found in the central and northern portions of the State. The surface of the country preserves unmodified by ice action all of the sculpturing left by the agents of erosion since the elevation of the regions above the sea.

Two very different types of topography occur in this area. Over the western and southern portion, where sandstone is the predominant rock, high narrow and crooked ridges with deep intervening valleys constitute the characteristic configuration. The larger ridges have a general east and west direction corresponding to the direction of the principal streams. Running off from the larger ridges are numerous smaller ones cut out by secondary streams, and these are indefinitely lobed.

The crests of the ridges rise from 200 to 350 feet above the valleys. A few prominent points on the ridges rise considerably higher than this. Mt. Arie, near West Baden, and Burtin Hill, southwest of French Lick, are two of the highest points in this region. Toward the northeast the ridges become less prominent until they are nearly entirely replaced to the east of Orangeville by a comparatively level limestone country, the surface of which is pitted with numerous "sink holes," or cone-shaped basins, usually ten to twenty yards across, and from eight to fifteen feet deep, connecting through openings at the bottom with underground drainage channels in the limestone. Sometimes these "sink holes" cover one or more acres, and by the filling up of the subterranean outlet they are frequently transformed into ponds. The "sink holes" constitute the most characteristic feature of the topography between Orangeville and Orleans.

DRAINAGE.—Two streams, the Patoka River and Lost River, with their tributaries drain most of this region.

Lost River has its source in the St. Louis limestone region in the western part of Washington County. In the northeastern part of Orange County (Sec. 4, Tp. 3 N., R. 1 E.), it sinks and flows for a distance of about eight miles through an underground channel in the lower Kaskaskia limestone. Through the region where the channel of Lost River is underground numerous basins and ravines ending in "sink holes" collect the surface waters and transmit them through underground channels to the main stream. Two of these underground streams come to the surface and disappear again in a large sink hole called the "Gulf," about a quarter of a mile northeast of Orangeville. It is evident that the two streams which unite here have their sources distant from each other from the fact that rains in a quarter which renders one of them turbid do not affect the other.

Lost River leaves the underground channel at Orangeville. The old surface channel or "dry bed" unites with the stream a short distance below the "rise." This channel is dry, except after heavy rains, when the excess of water continues down from the first sink to three other sink-holes in sections 8, 13 and 11, Tp. 3 N., R. 1 W. The increase in the volume of water at the "rise" at such times causes it to flow backward up the old channel until it is filled, thus presenting the curious phenomenon of a stream flowing in two directions at the same time.

Below Orangeville Lost River meanders much, but keeps a general westerly course to White River in Martin County. A comparison of the distance in a straight line between Orangeville and the junction of Lost River and White River, with the actual length of the stream between these two points, will indicate the extent of its meanders. The distance from Orangeville to the mouth of Lost River in a bee line is about 15 miles. In covering this distance the stream traverses more than 36 miles. Throughout its course Lost River is sluggish. Below Orangeville the valley plain or bottom is usually a quarter to a mile in width In some places the channel of the stream is cut in the alluvial material of this plain, while in others it is in limestone or sandstone.

The Patoka River and its branches drain the southern part of Orange and the northeastern part of Dubois counties. The Patoka is similar to the Lost River in its sluggish character and extensive meandering. A striking peculiarity of the Patoka is its great length as compared with its volume. Its comparatively small volume is due to the small drainage area, which it divides with two other streams, the Ohio and the White rivers, lying on either side of it. The valley of the Patoka is cut through the Kaskaskia beds and the Mansfield sandstone. At the contact of the limestone and sandstones numerous springs break forth, furnishing an abundance of excellent water.

GEOLOGY.

GENERAL RELATIONS.—The rocks of the whetstone region all belong to the Mississippian or Lower Carboniferous formations. The subdivisions of these and their taxonomic relations are indicated below:

System.	*Series.*
Carboniferous	Coal Measures. Mansfield sandstone.
Mississippian	Kaskaskia.

The beds have a gentle dip to the southwest, so that in passing across the region from east to west the Kaskaskia beds, which are the predominant and almost the sole rocks in the east, are seen to pass under the Mansfield sandstone, and are found in the west only in the bottom of the valleys.

All of the Kaskaskia Limestone beds of this region, and the sandstones below the uppermost of these, are referred to the Kaskaskia group. It comprises, where typically developed, three beds of limestone and two of sandstone. These different beds will be designated respectively as the Lower, Middle and Upper Kaskaskia Limestones, and the Lower and Upper Kaskaskia Sandstones. The following section of Kaskaskia strata taken at Foote's Spring in S. W. ¼ of S. W. ¼, Sec. 11, T. 1 N., R. 2 W., shows about the average thickness of its different beds except the Lower Kaskaskia Limestone, which is only partially exposed at this point:

Slope with Mansfield Sandstone fragments	18 feet.
Upper Kaskaskia Limestone	15 feet.
Upper Kaskaskia Sandstone	35 feet.
Middle Kaskaskia Limestone	16 feet.
Lower Kaskaskia Sandstone	30 feet.
Lower Kaskaskia Limestone	6 feet.
Blue Shale	3 feet.
Lower Kaskaskia Limestone	5 feet.

LOWER KASKASKIA LIMESTONE.—The Lower Kaskaskia Limestone is usually a light ash gray in color. In structure it is a close, fine textured, uncrystalline stone breaking with subconchoidal fracture. This stone is so fine and even textured that it would make in many places a lithographic stone, but for the presence of very fine seams of calcite running through it. Rough irregular shaped nodules of chert, gray to blue or black in color, occur in this limestone at some localities.

A thin bed of sandstone occurs at some localities in the upper part of this limestone which contains numerous stems of *Sigillaria*. This Sigillaria bed is well exposed at the forks of the road just west of Buck Grove Church, and at William Shirley's, S. E. ¼ of N. W. ¼ Sec. 12, T. 2 N., R. 2 W.

DISTRIBUTION.—Over the eastern and northeastern part of the region the Lower Kaskaskia Limestone is the principal formation. The Upper Kaskaskia beds have been almost entirely removed over the region east of Orangeville. This limestone extends down the Lost River Valley about two miles below Roland Postoffice. Above this point it extends well up the valleys of the tributaries of Lost River. The Lower Kaskaskia Limestone does not extend so far west along the Patoka. It dips below the bed of the stream in the east part of Sec. 16, Tp. 1 S., R. 1 W.

LOWER AND UPPER KASKASKIA SANDSTONES.—These beds which are separated by the Middle Kaskaskia Limestone vary widely in thickness and in lithological characters. They are composed of strata of sandstone of medium coarseness, buff to light gray or white in color. In many places iron in the form of limonite concretions occurs in the massive sandstone. Thin seams of coal three to six inches in thickness are found in them at some localities. One of these thin Kaskaskia seams has been opened in the S. W. ¼ of the S. W. ¼ Sec. 24, Tp. 2 N., R. 2 W. Beds of shale sometimes in part replace the sandstones. The Lower and Upper Kaskaskia Sandstones outcrop extensively along the valleys of the Upper Patoka and Lost Rivers, and of their tributaries. The distribution of the outcrops of these shales which are of economic value will be given in detail in another part of this report.

MIDDLE KASKASKIA LIMESTONES.—This limestone is usually a close-textured, semi-crystalline, gray limestone. It is usually fossiliferous containing a rich brachiopod fauna. At some localities the Middle Kaskaskia limestone has a perfect oölitic structure developed. This structure is well shown at the spring on the north side of the road in the N. E. ¼ Sec. 4, Tp. 1 N., R. 2 W. Two systems of planes nearly at right angles to each other are often developed in this limestone. Weathering always proceeds most rapidly along the joints of these planes when they are present. In such a ledge weathering reduces the limestone to a mass of chips and slabs split off parallel with the bedding, and with trough or ditch-like depressions running through the mass of debris corresponding in position to the original joints. Where one of these troughs of weathering is much more thoroughly developed than the others, as often happens along the terrace of a hill, the resemblance to an artificial stonework thrown up by man is often striking. Good examples of this kind of weathering occur in the N. E. ¼ Sec. 28, Tp. 2 N., R. 2 W., and south of Geo. Pruitt's in the N. W. ¼ Sec. 3, Tp. 2 N., R. 2 W.

The Middle Kaskaskia limestone varies in thickness from 30 to 5 or 6 feet. Its distribution is nearly coextensive with that of the Upper Kaskaskia limestone, which is indicated on the map by the line of contact between the Mansfield sandstone and the Kaskaskia.

UPPER KASKASKIA LIMESTONE.—The Upper Kaskaskia limestone is the highest of the Kaskaskia series. It is a dark to light gray, usually crystalline limestone, composed largely of crinoid stems. This limestone is usually characterized by an abundance of *Archimedes*. This fossil is comparatively rare in the middle limestone. Like the middle limestone the Upper Kaskaskia is sometimes oölitic in structure. Sometimes it has bands of chert two or three inches or more in thickness running through it. These chert bands are of slight lateral extent and thin out to attenuate edges. They are the result of the replacement of the limestone by silica. Crinoid stems and other fossils which have been perfectly silicified occur in the chert.

DISTRIBUTION.—The distribution of the Upper Kaskaskia limestone is sufficiently indicated on the map. All of its outcrops will be found near the line separating the Mansfield sandstone from the Kaskaskia limestone.

MANSFIELD SANDSTONE.

Mansfield sandstone is the name given by Mr. T. C. Hopkins, of this survey, to the sandstones and associated strata lying above the subcarboniferous limestone and below the coal measures. The term is equivalent to Conglomerate heretofore used in the Indiana reports for this horizon.

The Mansfield sandstone comprises in this region a series of strata from 150 to 200 feet in thickness, which vary greatly in lithologic features, both laterally and vertically. Sandstone ranging in texture from coarse conglomerate to the fine-grained Hindostan whetrock constitutes the bulk of the formation. Interbedded with the sandstone are thin beds of coal, shale and fire-clay. The Mansfield sandstone generally contains a considerable amount of iron, which is concentrated in limonite nodules and bands of highly ferruginous sandstones.

DISTRIBUTION.—The map indicates in detail the distribution of the Mansfield sandstone over this area, but some account will be given here of the lithologic characters of the formation in the different portions of the region.

Southeast of French Lick the Mansfield sandstone is represented only by detached remnants 15 to 40 feet thick on the top of the higher ridges and hills. In this quarter the sandstone is usually coarse, containing much iron, with occasional thin strata of small quartz pebbles.

South of the Patoka, in southwestern Orange and in Dubois County, the Mansfield sandstone consists of thick beds of massive sandstone. Southeast of Centerville, in sec. 30, the sandstone is characterized by marked cross-bedding. West and southwest of Ellsworth, in Dubois County, the sandstone outcrops frequently at the head of or along the sides of deep ravines, in cliffs of massive, loosely cemented, coarse buff sandstone, 30 to 80 feet high.

Between the Patoka and Lost rivers, in Dubois, Martin and western Orange, the Mansfield sandstone has developed in it, in some localities, thin seams of coal, ten to twenty-four inches thick, and associated beds of shale and fire-clay. At Sutton's coal bank, in the S. W. ¼ of the S. W. ¼ Sec. 27, Tp. 1 N., R. 3 W., the coal is 24 inches thick. The section exposed there is the following:

Coarse sandstone	? feet.
Gray shale	8 feet.
Coal	24 inches.
Fire-clay	9 feet.
Upper Kaskaskia limestone	? feet.

West of French Lick and West Baden and northwest of Orangeville, the Mansfield sandstone includes the very fine-grained sandstone beds which furnish the Hindostan whetstone.

The conglomerate structure of this formation is best developed in the sandstone cliffs at Shoals and southwest of there. On the east side of the river, at the High School building, a bed of massive sandstone forty feet thick outcrops. This sandstone is composed of loosely cemented coarse sand with some mica and numerous well rounded quartz pebbles. The stone has distinct cross-bedding dipping southeast. This is well shown in the sidewalk, just north of the railroad in Shoals, which is cut out of the sandstone in place. A half mile north of Shoals the sandstone is well exposed in vertical cliffs on the west side of the river. At the "Pinnacle" the section is approximately as follows:

Mansfield Sandstone	110 feet.
Upper Kaskaskia Limestone	10 feet.

The sandstone here is a dark buff, coarse grained stone containing much muscovite mica. Quartz pebbles are sparingly scattered throughout the thickness of the sandstone. At intervals they are aggregated together in sufficient abundance to form a typical conglomerate structure.

The sandstone is rather loosely cemented and sometimes weathers into striking forms. One of the most interesting results of weathering is seen in the "Jug Rock,"* which is a quarter of a mile north of West Shoals. The "Jug" is a pillar of conglomerate sandstone about forty feet high standing on the slope of a hill. The lower portion is about sixteen feet in diameter, while toward the top it diminishes to about five feet. The top is surmounted by a slab of much harder stone about

*An excellent reproduction of a photograph of this rock is found in the Report of this Department for 1870.

twenty-three feet in diameter. The general outline gives the impression of a jug if the observer has a sufficiently vivid imagination. The surface of the pillar is marked from top to bottom with distinct cross-bedding.

The Upper Kaskaskia Limestone, which underlies the sandstone about "Jug Rock," is absent from the section at Shoals, the sandstone extending down to the level of the river bed. A half mile south of Shoals the limestone reappears in the river bank showing a thickness of eight or ten feet; vertical cliffs of sandstone sixty or seventy feet high resting upon it. The limestone and sandstone with occasional conglomerate structure continues as far down the river as Johnson and Chenoworth's kaolin bank in Sec. 27, beyond which I have not traced it. At the kaolin bank the section is:

1. Conglomerate Sandstone........................40 feet.
2. Kaolin.. 4 feet, 6 inches.
3. Limestone.....................................14 feet.

The sandstone here is a typical quartz pebble conglomerate. A geode was seen imbedded in the sandstone near this section. Geodes which have weathered out of the sandstone are common on the surface of the ground in Sec. 27, Tp. 3 N., R. 4 W. One was seen ten inches in diameter. Geodes which have weathered out of the conglomerate are also frequently seen in and about Shoals. These geodes appear to be identical in every respect with those which occur so abundantly in the Keokuk Limestone in the counties to the north and east of this region. If these geodes have been derived from the Keokuk, as they seem to have been, then the Keokuk beds to the north or east must have been elevated above the sea a sufficient length of time to have been considerably eroded previous to the formations of the conglomerate beds. Kaskaskia and Keokuk rocks doubtless formed the shore line of the Carboniferous Sea across a part of the southwestern portion of the State, while the Mansfield Sandstone was being deposited. The streams eroding these rocks set free the geodes and carried them to the shallow coast waters, whence they were transported by wave action to their present position in the conglomerate beds.

At three or four points in Martin County north of Lost River the relations of the Mansfield sandstone and Upper Kaskaskia limestone observed seemed to indicate erosion of the limestone subsequent to the deposition of the sandstone. The presence of superficial deposits over the direct contact of the two at the critical points make the presence of unconformity not quite certain.

Along the branch in the west part of the sections 17 and 20, Tp. 2 N., R. 3 W., a bed of limestone 10 to 50 feet thick outcrops below the conglomerate sandstone. Near the intersection of the one-half mile line and the north and south line of Sec. 17, Tp. 2 N., R. 3 W., on the east side of the road, the line of contact of the two suddenly descends, the base of the sandstone being 8 or 10 feet lower than before. Similar relations of the two exist near the center of Sec. 8, Tp. 2 N., R. 3 W., on the south side of the ravine heading at Frank Felkaroi's; also in the S E. ¼ of S. E. ¼ of Sec. 5, Tp. 2 N., R. 3 W., opposite A W. Stuart's.

At the B. & O. S. W. R. R. cut in the S. W. ¼ Sec. 29, Tp. 3 N., R. 3 W., a section 20 feet thick is exposed. It consists of a light gray sandstone in strata ½ to 2 inches thick, interbedded with dark blue clay. At another cut on the same road, in the N. W. ¼ Sec. 22, Tp. 3 N., R. 3 W., about 55 feet of sandstone, mostly thin bedded, is exposed.

COAL MEASURES.—An area embracing about six square miles to the southeast of Shoals, including the higher part of the water-shed between the Lost River and the White River, is referred provisionally to the Coal Measures. These beds have not been directly correlated with the Coal Measures to the west by tracing their connection across the country, but their lithological characters seem to indicate that they are the easternmost outlines of the true Coal Measures The character of the strata at the horizon is well shown at Sampson's Hill, S. E. ¼ of N. E. ¼ Sec. 6, Tp. 2 N., R. 3 W. The section there is approximately as follows:

1.	Upper hill slope, loose fragments gray sandstone not in place	15 feet.
2.	Dark blue potter's clay	6 feet.
3.	Shaly impure coal	1 foot.
4.	Light gray silicious clay	4 feet 6 in.
5.	Thin shelly sandstone	4 feet.
6	Hard light gray, rough bedded sandstone	6 feet.
7.	Clay, light gray with thin strata of limonite and limonite nodules	12 feet.
8.	Clay and sandstone	25 feet.
9.	Coal	3 feet.

CHAPTER II.

HINDOSTAN WHETSTONE.

LITERATURE.

OWEN, DAVID DALE.—In the year 1838 David Dale Owen visited one of the Hindostan whetstone quarries while making a geological reconnoissance of the State and afterwards published* a brief description of the stone. He states that the Hindostan whetstone had at that time a good reputation in the market. No fossils had then been found in the whetstone except the impressions resembling worm trails.

OWEN, RICHARD.—Richard Owen, Assistant State Geologist. visited Orange County in 1859. In a very brief description† of the Hindostan

*Report of a Geol. Reconnoissance of the State of Indiana, 1838, p. 16.
†Report of a Geol. Reconnoissance of Indiana, 1859-60, p. 144.

whetstone he gives the names of the men owning quarries at that time and mentions the well preserved ferns and Lepidodendra occurring in the whetstone.

Cox, E. T.—In the report on Martin County,* Professor Cox states that Hindostan whetstones and grindstones are extensively manufactured from sandstones lying between the "upper archimedes" limestone and the oölitic limestone bed in the southeastern part of Martin County. Cox evidently confused the Hindostan stone with the coarse sandstone beds, since the former lie above both of the mentioned limestones. The account was doubtless written without visiting the part of the county mentioned, for whetstones have never been manufactured there except to a very limited extent.

Five years later Cox published† in his annual report a list of seven species of plants from the whetstone determined by Leo Lesquereux.

SMITH, S. I.—Several years ago a fossil insect wing found in the Hindostan whetstone quarry of Mr. T. V. Braxton, near French Lick, was presented to the Hanover College Museum, where it is at present. Prof. E. T. Nelson, of Hanover, sent the specimen to Yale College to be studied. It was described and figured‡ by Sidney I. Smith, who named the insect *Paolia vetusta*. The locality of the specimen in this description is incorrectly given as a "grit" quarry near Paoli.

LESQUEREUX, LEO.—In the Coal Flora,§ Lesquereux gives a list of fossil plants from the whetstone beds of Indiana, including three species of Lepidodendra and seven ferns.

ELROD AND MCINTIRE.—In 1875 Dr. M. N. Elrod and Dr. E. S. McIntire published‖ a report on the Geology of Orange County. In this report they refer the Hindostan whetstone beds to the Conglomerate or Millstone Grit on the authority of Leo Lesquereux, to whom fossils were submitted. A brief description of the whetstone is given.

GRISWOLD, L. S.—While preparing a report on the whetstones of Arkansas, L. S. Griswold visited the Hindostan whetstone quarries and published¶ an accurate description of the process of quarrying and manufacturing the stone. He also gives the results of a microscopic examination of one slide of Hindostan stone. Mr. Griswold makes the statement** that the Hindostan stone was first discovered and worked at Hindostan Falls, about 1850. This is an error, since no Hindostan stone is known to occur nearer to Hindostan Falls than ten or twelve miles. The stone was well known at least as early as 1838.***

*Geol. Surv. of Indiana, 1870, p. 105.

†Geol. Surv. of Indiana, 1875, p. 7.

‡Notice of Fossil Insect from the Carboniferous Formation of Indiana. Am. Jour. Sci., Ser. III, Vol. 1, pp. 44-46.

§2d Geol. Surv. Penn. Coal Flora, Vol. III, p. 852.

‖Geol. Surv. Indiana, 1875, pp. 205-238.

¶Geol. Surv. of Arkansas, Vol. III, 1890.

**Loc. cit., p. 82.

***Geol. Reconnoissance of Indiana, 1838, p. 14.

HISTORICAL SKETCH.

The Hindostan whetstone rock was first discovered and used early in this century. Joel Charles, who built a fort on the present site of the French Lick Springs Hotel, is said to have first discovered the stone about 1810. Wm. Kliphart and John Pinnick opened the first whetstone, where the Braxton quarry is now located, about 1825. At first the whetstone was taken from the quarry and shipped in the rough down Lost River in flatboats to Hindostan, in Martin County, where it was manufactured. The Brooks Bros. operated a whetstone quarry at this place for a number of years. From Hindostan the stone was shipped to the New Orleans market in flatboats, and came to be known by the name of the place of manufacture. The old factory has long been abandoned, and the town itself is extinct; but the name Hindostan remains inseparably attached to the whetstone. At New Albany Mr. Wm. Galbraith and Mr. J. G. Wright erected a whetstone factory in the year 1855.* They manufactured Hindostan whetstone until succeeded by Mr. F. C. Dishman, who manufactured both Arkansas and Hindostan stone at New Albany. In 1889 this factory was closed because of sharp competition in business. After the death of Mr. Dishman in 1893 the factory was sold for other purposes.

A small factory was formerly operated at Jeffersonville, Indiana, by Mr. Lewis. Only a small amount of stone was produced here. All of the Hindostan stone produced at present is manufactured in mills near the quarries.

Until three years ago the owners of the different whetstone quarries disposed of their output independently to various dealers. Since 1892 the Pike Manufacturing Company, of Pike Station, New Hampshire, has contracts with the owners of all active quarries for their entire output.

DESCRIPTION.—Hindostan stone from different quarries and from different strata in the same quarry presents considerable variation in physical characters. The best grade of stone, which is called "Washita finish" stone, from its resemblance to the Arkansas Washita stone, has a creamy white color and a hardness of about 3. Most of the other grades of stone are light gray to bluish gray in color and slightly softer than the "Washita finish" stone. Some of the stone called Orange stone has an orange tint. Occasionally the strata are colored with iron to various shades of red. Frequently alternate layers of the stone have different shades of color, giving a prettily banded structure. Sometimes the penetration of the iron laterally from the joint seams results in a banded structure running vertically through the stone instead of horizontally. The red stone is not used for whetstones, but many fancy articles

* Letter to the writer from Mrs. F. L. Dishman.

are carved from it. In some layers of the stone iron and manganese are disseminated through it in minute masses, giving it a closely speckled or peppered appearance. Dendrites of manganese sometimes occurs on the surface of the whetstone strata.

STRUCTURE.—Thin sections of the strongly marked varieties of the stone have been examined by the microscope. The examination shows the stone to be composed of very fine quartz grains. Some of these are as small as .01 mm. in diameter, while the largest measured was .0325 mm. in diameter. The great bulk of the grains are of a nearly uniform size, averaging about .02 mm. The quartz grains have generally somewhat rounded outlines, though some are distinctly angular. Some scales of mica and occasional small crystals of tourmaline are associated with the quartz grains. A few crystals of zircon and some chlorite occur in the stone.

Small masses of limonite are disseminated through all of the sections. In a slide of "Washita finish" stone from Chaillaux's quarry the iron is distributed among the quartz grains in numerous small brown and black masses. In a slide of the bluish gray Hindostan stone from Moore's quarry the limonite is more abundant, some of it occurring in lathe-shaped masses $\frac{1}{3}$ mm. in length by .05 mm. in diameter.

A thin section from the old Jackman quarry, one mile northwest of Roland, shows the extreme type of the ferruginous Hindostan stone. The limonite in this stone is in irregular masses, many of which are $\frac{1}{3}$ mm. in length. These limonite masses are fringed with numerous tooth-like projections and often terminate in clusters of sharp needles.

All of the slides are somewhat clouded with earthy matter, distributed through the ground mass. This is slight in the "Washita finish" and light colored stone, but quite marked in the bluish gray stone. The cementing material seems to be the earthy matter and iron disseminated through the stone. Pieces of the stone left standing for several days in strong hydrochloric acid remained unaltered, showing that no carbonate is present as a cement.

MANUFACTURE.—Most of the whetstone is manufactured at small mills situated near the quarries and run by horse-power. A horse-power whetstone mill comprises a circular open shed forty or fifty feet in diameter sheltering the team and driver, and a smaller closed shed at one side, in which the rub-wheel is placed. The power is supplied from a heavy vertical shaft of wood set in the center of the large shed. A horizontal pole to which the team is attached projects from the lower part of this shaft, while from the upper part projects several horizontal wooden shafts, twelve or fifteen feet in length, over the bifurcate ends of which passes a heavy rope connecting with the shafting in the rub-wheel shed. The rub-wheel consists of a cast iron disk about one inch thick and from four to six feet in diameter. This revolves horizontally and is supplied with sand and water, while the sandstone is held against it by hand. Four of these mills are located near the quarries northwest of French Lick.

At Paoli, Braxton Brothers have erected a steam whetstone mill. It is not used at present, however, their stone being manufactured near the quarry. Mr. J. A. Chailleaux owns and operates a well equipped whetstone factory, which is furnished with a steam engine, three miles northwest of Orangeville. This factory is furnished with two rub-wheels and has a capacity of 1,200 pounds of stone per day.

The whetstone rock lies in layers often exactly the thickness of the whetstones. When thicker than desired the strata split readily to the required thickness. The stone is taken from the quarry in rough slabs three or four feet across. These are ruled off with a scribe awl into spaces corresponding to the size of the whetstone to be made. The slab is then broken into pieces along the ruled lines by means of a chisel and hammer. The rough whetstone thus prepared is taken to the mill where it is ground smooth on the rub-wheel. The sand used in grinding is obtained by pulverizing the coarse sandstone, which is abundant about the quarries. An average day's work at grinding is 300 pounds of large stone, or 125 pounds of small stone. Women and girls sometimes assist at the rub-wheel. As soon as the stone is ground smooth it is washed and then stacked up in sheds and allowed to dry thoroughly before packing. The drying produces a lighter color and hardens the stone slightly. Before shipping, the stone is packed in boxes called "cases," each holding about 100 pounds.

KINDS AND USES.—Several different sizes and varieties of whetstones are manufactured. A class of stones intended for carpenter's and bench use is made in two sizes, viz.:

No. 1 Regular, 8 x 2 to 2¼ x ¾ to 1½ inches.
No. 1 Small, 8 x 2 x ½ to 1 inch.

A white or buff stone with a smaller proportion of earthy matter than the ordinary is branded as "Washita Finish" stone and sold at a slightly higher price than No. 1 Regular.

About one-half dozen different sizes and shapes of small thin stones, with rounded edges, are made and sold under the name of "slips." These are used mainly by carpenters in sharpening gouges, bedding planes and similar instruments.

A considerable number of axe stones 2½ inches square by ½ inch thick are manufactured. These are used largely in the pine regions.

The glass-maker's file is a stone 8 inches long by ¼ to ¾ of an inch square. It is used by glass-makers in finishing glass work, and also for sharpening some kinds of tools.

The hacker stone is about 8 inches in length and of oval form. It is used in the turpentine regions to sharpen the broad-bladed hacker knives with which the incisions are made in the turpentine trees. About 400 gross of this stone and 40 to 50 gross of scythe stones are made annually.

The doctor stone is a large stone 4 x 4 x 2 inches in size, used in the calico mills to sharpen "print doctor" knives which are used to remove ink from the cylinders on which calico is printed. From 3,000 to 4,000 pounds of these are manufactured annually. Orange stone is the name given to a variety of the stone having a pale orange color.

A few razor hones are manufactured, nearly all of which are sold to the visitors at French Lick and West Baden Springs.

Besides whetstones, there are a considerable number of fancy articles such as books and paper weights made from the whetstone rock and sold to visitors at the Springs for souvenirs. The banded and colored strata are selected for this purpose. Mr. Gabriel Dougherty, who makes most of these articles, estimates that about $300 worth of them are sold annually.

LABOR EMPLOYED.—About 25 men are engaged in the Hindostan whetstone business during part of the year. Some of the quarries are owned by farmers who close them during the summer while tending their crops. Mr. J. A. Chailleaux and Braxton Bros., each employ six to eight men during most of the year. The other quarries, when running, use about three men each. Laborers receive from 65 cents to $1.00 per day.

OUTPUT AND PRICES.—About 300,000 pounds of Hindostan stone were manufactured in 1894. Of this amount the output of the several producers was approximately as follows:

J. A. Chailleaux, Huron	109,000 pounds.
Braxton Brothers, Paoli	100,000 pounds.
Brown Moore, French Lick	20,000 pounds.
Gabriel Dougherty, West Baden	20,000 pounds.
Wm. Able, French Lick	20,000 pounds.
W. F. Osborn, Louisville, Ky	11,000 pounds.

The prices received by the quarrymen for the finished stone vary according to its size and shape. For the larger sizes 1½ to 2 cents per pound is received. For the smaller kinds, which require more labor to manufacture, the prices are from 3 to 5 cents per pound, wholesale. The Hindostan stone retails at from 5 to 30 cents per pound, according to the size and quality.

CHAPTER III.

COARSE SANDSTONE WHETSTONE.

DESCRIPTION.—The sandstone from which the coarse whetstones are made is a white or very light colored, loosely cemented, porous rock composed of coarse quartz sand. Some muscovite mica occurs through the stone. Iron in the form of limonite or pyrite concretions about the size of a pea also sometimes occurs. Stone containing small iron concretions is avoided as much as possible, but it is difficult to find it entirely free from them.

The microscope shows the quartz grains composing the stone to have a diameter of about .14 of a millimeter. In the Hindostan stone the quartz grains average .02 of a millimeter in diameter.

MANUFACTURE.—The manufacture of coarse whetstone was begun as early as fifty years ago by Nathaniel Spaulding. When the industry began, the gang saw used at present to cut the stone was unknown, and the stone was sawn in the ledge by hand.

All of the coarse whetstones are quarried and manufactured about three and one half miles southeast of French Lick, along French Lick Creek. Four quarries are operated at present. The stone occurs in massive beds, from twenty to thirty-five feet thick, which outcrop along the valleys of the streams. Only the lightest colored part of the bed is used for whetstone. Usually only five or six feet of ledge is sufficiently white and free from iron to be used. The rock is blasted or wedged out of the ledge in blocks, which can be conveniently dragged at the end of a chain by a pair of horses to the mill. The stone is sawed into slabs the thickness of the finished whetstone by a gang saw run by horse power. The block to be sawed is placed under a rectangular frame fitted with eight to twelve thin strips of iron about three inches wide. The four corners of the gang frame are supported by ropes which are connected with a single rope passing over a wheel and having one end weighted. This arrangement permits the saws to descend on the rock as it is cut. The forward and backward motion of the gang saw is transmitted from the horse power through a piece of shafting, which at one end is connected with the large cogwheel revolved by the team, and through a wheel at the opposite end with a wooden shaft at right angles to it, which is attached to the gang saw. During the process of sawing the stone is kept supplied with water. The sawed slabs are deeply marked with a scribe awl and broken into rough whetstones; these are rubbed smooth by hand on a block of similar stone. The machinery used in a sawing plant costs about $8,000.

KINDS.—Four principal sizes of whetstones are made. These are known to the trade as "medium sand," "small sand," "large table" and "small table" stones. The "medium sand" is a stone 1½ inches square and 8 inches long. "Small sand" stones are 1¼ inches square and 8 inches long. The "large table" is 5x2¾x10 inches in size; while "small table" stones are 2¾ inches square by 10 inches long.

This stone is well adapted to produce a very coarse harsh edge. It is largely used for shoemakers' and fishermen's knives. The extreme brittleness of the stone renders it liable to break readily on rough handling.

OUTPUT.—The total output of the coarse whetstone quarries for the year 1894 was about 15,000 pounds. Of this amount Mr. Solomon Lashbrook, of French Lick, and Mr. Wm. F. Osborn, Louisville, Ky., produced each about 6,000 pounds. Mr. David Bledsoe, of French Lick, produced about 2,000 pounds, and Mr. Stephen Flick about 1,000 pounds. Twelve to fifteen men are engaged in the quarries when they are running.

All of the coarse whetstone at present made is bought by the Pike Manufacturing Co., of Pike Station, New Hampshire. The quarrymen receive one cent per pound for the finished stone. In 1886 the stone was worth three cents per pound. The lower price has greatly reduced the average annual output. There is probably not more than one-fourth as much coarse whetstone manufactured now as ten years ago. The coarse whetstones retail at five to eight cents per pound.

CHAPTER IV.

RELATIVE VALUE AND IMPORTANCE OF INDIANA WHETSTONES.

The comparative importance of the Indiana whetstone industry can best be indicated by giving a brief account of the production of whetstones elsewhere in the United States. There are but eight States in which whetstones are manufactured for more than local use. These are Arkansas, Missouri, Indiana, Michigan, Ohio, New York, Vermont and New Hampshire.

ARKANSAS.—Arkansas furnishes two kinds of whetstone, the Arkansas and the Ouachita stones. The Arkansas stone is made from novaculite, a white stone composed of nearly pure silica, and having about the hardness of quartz. The Ouachita stone differs from the Arkansas stone mainly in being much more porous. The abrasive qualities of both depend upon the presence of minute cavities formed by the leaching out of calcite rhombs.*

*Novaculites of Arkansas, Vol. III, 1890.

The Arkansas stone is used largely for sharp pointed instruments and tools requiring a very fine edge, such as engravers', surgeons' and jewelers' instruments The best quality of Arkansas bench stone is quoted at $4 a pound; while the best grade of Ouachita sells at 60 cents per pound.

MISSOURI.—The Missouri whetstone is sold under the name of Adamascovite grit. It is manufactured at Pierce City, Missouri, by the Adamascovite Stone, Lime and Mining Co. The whetstone is made from a compact, fine-grained, rather soft sandstone, resembling somewhat the Hindostan stone. Only about 8,000 pounds per annum are manufactured. It retails at from 50 to 65 cents per pound.

MICHIGAN AND OHIO.—The production of whetstones from these two States is controlled almost exclusively by the Cleveland Stone Co., of Cleveland, Ohio. Berea, Ohio, and Grindstone City, Mich., are the principal places of manufacture in these States. Most of the whetstones made are scythe stones. They sell at from $5 to $17.25 per gross.

NEW YORK —A whetstone known as Labrador stone was formerly quarried at Labrador Lake, in Courtland County. This quarry is not worked at present, however. The only whetstone made in the State is Arkansas oil-stone, which is made at Manlin's Station by the Pike Manufacturing Co.

NEW HAMPSHIRE AND VERMONT.—All of the quarries of these two States are operated or controlled by the Pike Manufacturing Co., which has factories at Evansville, Vermont, and Pike's Station, New Hampshire. Scythe stones constitute the larger part of the whetstone product of these States. They are manufactured mainly from schists. Some of the principal brands of Vermont stone are the "Black Diamond," "Tamoille," "Green Mountain," and "Willoughby Lake." The "Indian Pond," "Chocolate" and "Farmer's Choice" are New Hampshire stones. These stones sell at from $5 to $24 per gross.

INDIANA.—For the past three years the Pike Manufacturing Co. has controlled the output of the Indiana whetstone quarries. This has resulted in increasing slightly the price of the stone to the quarrymen and in producing a better quality of whetstones. The Hindostan 8x2 inch stone retails at from 8 to 12 cents per pound, while the Hindostan slips bring from 20 to 40 cents a pound. The coarse sandstone retails at from 5 to 8 cents per pound.

STATISTICS.—The following table* gives all the available statistics of whetstone productions in the United States for the years 1892 and '93:

* Mineral Resources of the United States, 1893, p. 673.

Production of Whetstones by the Pike Manufacturin Co. in 1892 and 1893.

State.	Kinds.	Output, 1892.		Output, 1893.	
		Pounds.	Value.	Pounds.	Value.
Arkansas	Washita stone	400,000	$60,000	300,000	$45,000
	Arkansas stone	20,000	12,000	12,000	12,000
New York	Labrador stone	500	50	200	20
Indiana	Hindostan stone	300,000	15,000	250,000	13,000
	Sandstone	100,000	2,000	100,000	2,000
Vermont and New Hampshire	Chocolate stone	20,000	2,000	20,000	2,000
	Scythe stones	16,000	50,000	13,000	40,000
	Total......Pounds	856,500	$141,050	682,000	$114,020
	Gross	16,000		13,000	

Markets.—From 50,000 to 60,000 pounds of Hindostan stone is exported annually. About 30,000 pounds of this goes to the European market. Less stone is shipped to Europe than formerly because of the reduced price of the product of trans-Atlantic quarries. Australia, South Africa and South America take annually from 20,000 to 30,000 pounds. The larger part of this amount goes to Australia and the Colonies. The coarse whetstone is not exported extensively because of its liability to breakage in long transportation. From 6,000 to 8,000 pounds are shipped to South America annually.*

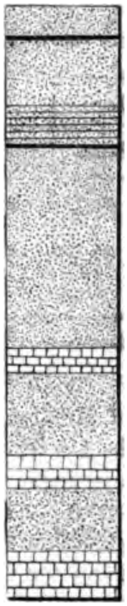
A limited amount of Hindostan stone is sent to Canada and Mexico. Whetstone shipped into Canada from the United States is subject to 30 per cent. duty. The Hindostan stone used in the United States is consumed largely in the Middle and Southern States. It would seem that a new market for the Hindostan stone could be developed in the Pacific Coast States. There are no quarries of any importance in these States. The principal whetstones used on the Pacific coast at present are the Washita stone from Arkansas and the Tam O'Shanter and Water of Ayre stones from Scotland.

CHAPTER V.

WHETSTONE BEDS.

As previously stated, two kinds of whetstones are quarried in the whetstone region from beds belonging to two distinct geological horizons. These are the Hindostan, and the coarse sandstone whetstones; or the "fine" and "coarse grits" of the quarrymen. Since both are not well developed at the same locality their relations may be shown by a generalized section.

* Letter from Mr. E. B. Pike, Pres. Pike Manufacturing Co., Nov. 29, 1895.



Mansfield Sandstone.	(11)	Coarse sandstone	14 feet.
	(10)	Coal	1 foot.
	(9)	Coarse sandstone	35 feet.
	(8)	Hindostan whetstone	20 feet.
	(7)	Coal	14 in.
	(6)	Coarse sandstone and shale	100 feet.
Kaskaskia.	(5)	Upper Kaskaskia limestone	13 feet.
	(4)	Upper Kaskaskia sandstone (coarse whetstone sandstone)	40 feet.
	(3)	Middle Kaskaskia limestone	15 feet.
	(2)	Lower Kaskaskia sandstone	35 feet.
	(1)	Lower Kaskaskia limestone	18 feet.

COARSE WHETSTONE BEDS.—The sandstone which furnishes all of the coarse whetstones quarried at present is the Upper Kaskaskia, No. 4 of the above section. This sandstone outcrops extensively along the upper Lost River and Patoka valleys and along their tributaries. It is only locally, however, that this bed has the proper lithologic characters for a whetstone. Along the valley of French Lick this stone is more generally suitable for whetstones than elsewhere. Along the upper portion of this valley this stone outcrops frequently in fine ledges thirty to sixty feet above the stream. The entire thickness of the sandstone bed is not apt to be sufficiently white and free from iron to be used for whetstone. Where suitable for whetstones the stone is a white, coarse-grained, friable sandstone, resembling loaf sugar. It contains no animal and but few plant fossils. The principal difficulty in collecting this stone is in getting that which is entirely free from iron nodules and concretions.

At Solomon Lashbrook's quarry (S. E. ¼ of S. W. ¼ Sec. 13, Tp. 1 N., R. 2 W.), the following section is exposed:

Middle Kaskaskia limestone	12 feet.
Sandstone	14 feet.
Slope of hill—rock unseen	45 feet.
Upper Kaskaskia limestone	4 feet.
Mansfield sandstone	3 feet.

The upper two feet of No. 2 is thin bedded and is quarried for grindstones. The four or five feet below it, which is quarried for whetstone, is a soft white sandstone with occasional small limonite concretions. The lower part of No. 2 is a brownish stone, unsuitable for whetstones, but a very good building stone.

At Stephen Flick's old quarry the ledge has been worked for about 200 yards along the brow of the ridge. The bed worked here is a white sandstone about five feet thick and quite free from iron. This quarry is located in the S. W. ¼ of the S. E. ¼ of Sec. 13, Tp. 1 N., R. 2 W.

Mr. W. F. Osborn and David Bledsoe own quarries in Sec. 18, a short distance above the Flick quarry. The quarries mentioned above are the only "coarse grit" quarries which are operated at present.

Quarries were formerly worked at the following localities:

S. E. ¼ Sec. 27, Tp. 1 N., R. 2 W.
N. W. ¼ Sec. 25, Tp. 1 N., R. 2 W.
N. W. ¼ Sec. 24, Tp. 1 N., R. 2 W.
N. E. ¼ of the S. E. ¼ Sec. 30, Tp. 1 N., R. 1 W.
N. E. ¼ of the S. E. ¼ Sec. 7, Tp. 1 N., R. 2 W.
N. E. ¼ of the N. E. ¼ Sec. 3, Tp. 1. S., R. 3 W.

Hindostan Whetstone Beds.—The Mansfield sandstone formation, in which the whetstone beds occur, varies greatly in lithological characters. Highly ferruginous coarse sandstones, fine-grained sandstones, shales, fire-clays and thin coal seams make up the formation. No single one of these beds, however, is co-extensive with the formation. Each of them has strong local developments, away from which they graduate into other lithologic types. The fine-grained sandstones and interstratified shales composing the Hindostan bed constitute one of these local lithologic phases of the Mansfield sandstone. The stratigraphic position of the whetstone bed is from 60 to 100 feet above the base of the Mansfield sandstone.

The Hindostan bed comprises about 25 feet of fine-grained sandstone, in strata from ½ inch to 2 or 3 feet in thickness, interbedded with shale. Several characteristic fossil plants are associated with the strata.

Geographical Position.—The Hindostan whetstone bed is practically confined to the northwestern part of Orange County, though traces of it occur along the southeastern margin of Martin County. The whetstone bed occupies only the upper portions of the higher ridges; the greater part of the original beds have been removed by erosion.

The valley of Lost River separates the whetstone area into two geographically distinct regions, which may be designated by the names of the towns nearest them, as the Orangeville and French Lick regions. The quarries of these two districts are distant from each other about nine miles. The Mansfield sandstone formation has been almost entirely eroded from this intervening area. That the whetstone bed formerly extended continuously between these now detached regions is indicated by its presence along the summit of the long north and south ridge, which terminates near Roland postoffice.

French Lick Region.—The character of the whetstone strata is such that they weather away on the hill slopes without leaving outcropping ledges, so that the rock can seldom be seen except where quarried. For this reason it is difficult to examine the structure of the beds toward their lateral limits or to determine exactly where these are.

The eastward extension of the beds near French Lick conforms to the outlines of the eastern slopes of the ridges west of French Lick Creek valley. To the east of this valley all of the Mansfield sandstone, where not entirely removed, has been eroded to a level lower than the horizon of the whetstone. Towards the south and west the beds appear to become coarser and pass into a sandstone not distinguishable from the ordinary coarse variety of the region. In the N. W. ¼ of the N. W. ¼, Sec. 1, Tp. 1 N., R. 3 W., and in the S. W. ¼ of the S. W. ¼ of the same section, outcrops occur along the road which seem to belong near the southwest edge of the whetstone beds. The stone is in thin layers and has the characteristic whetstone fossils, but is much coarser than at the quarries.

On the north the whetstone beds of the French Lick region extend no farther than the upper slopes of the high ridges facing Lost River.

All the quarries of the French Lick region lie on the slopes of the ridges from 40 to 100 feet below their summits. The largest and probably the oldest of them is the Braxton quarry in the S. W. ¼ of the S. E. ¼, Sec. 32, Tp. 2 N., R. 2 W. The following is the section at this quarry:

1.	Sandstone, coarse, yellowish brown	4 feet.	
2.	Clay-lead, gray, slightly silicious	5 feet.	
3.	Vegetable mold (black)		8 in.
4.	Sandstone, fine-grained, light gray; in strata two to eight inches thick with shaly partings	4 feet	6 in.
5.	Sandstone, fine-grain, light gray		14 in.
6.	Shale		6 in.
7.	Sandstone		26 in.
8.	Shale and sandstone, alternating in thin layers	3 feet	5 in.
9.	Sandstone	3 feet.	
10.	Coal (not seen)	1 foot	2 in.
11.	Shaly clay	7 feet.	
12.	Sandstone, coarse	60 feet.	
13.	Greenish shale	1 foot.	
14.	Sandstone, coarse	25 feet.	
15.	Limestone	6 feet.	
	Total	125 feet	8 in.

The stratum of coal (No. 10), which seems to underlie most of the quarries, marks the base of the whetstone grit. All of the stone used at this quarry comes from No. 9 of the section. To work this layer necessitates the removal of about 16 feet of the overlying strata. The layers above this do not split so readily.

The strata here, as in all of the quarries, are generally divided into rectangular or diamond-shaped pieces by narrow, vertical seams at intervals of a few feet. The sides of these seams are coated with iron oxide. Generally the iron ore is deposited on the edges of the strata, in the joints, as an incrustation from percolating waters which have dissolved it out of the coarse ferruginous sandstone overlying the whetstone. On being redeposited in the joints, the iron has penetrated the strata laterally, coloring them various shades of red and orange which fade out a few inches from the joints. Very little of this lateral penetration of the iron is seen in Braxton's quarry, but it is quite common in the "Red Quarry." The stone here is very light in color, contains but little earthy matter and makes an excellent whetstone.

On the opposite side of a deep ravine from this quarry is the quarry of Mr. Brown Moore in the northeast of northwest quarter, Sec. 5, Tp. 1 N., R. 2 W. This quarry was opened about 50 years ago. Although but a few hundred yards from the quarry described above, the character of the strata is quite different as will be seen from the following section:

		Feet.	Inches.
1.	Clay, gray and yellow, silicious	6	
2.	Sandstone, fine-grained, light gray		18
3.	Shale		21
4.	Sandstone	4	6
5.	Sandstone, bluish-gray, in layers ½ to 2 inches thick (whetstone rock)	10	
	Total	23	9

In No. 5 the stone is a bluish-gray color, and contains some argillaceous matter with very thin layers of clay between the strata. The surfaces of the strata have the rough or wavy appearance of ripple marks. The upper surface of the layer is always slightly softer than the lower. This fact is recognized and taken advantage of by the quarrymen, who always rule the slab with a scribe awl on the upper surface. The greater softness of the upper part of the stratum is probably due to that portion containing a larger per cent. of earthy matter than the lower.

In removing stone from this quarry the workmen have uncovered the trunk of a Lepidodendron, 12 inches in diameter, standing upright in the whetstone layers. About 6 feet of the trunk is exposed; the base was not seen, but probably rests in the thin layer of coal said to underlie the whetstone. The bark is altered to coal, while the interior of the trunk is replaced by sandstone identical with the whetstone, except that it is not stratified. The impression of another Lepidodendron, as large as the one described, occurs a few feet from it. Mr.

Moore states that the trunks of three others have been found standing upright in this quarry.

A short distance to the northwest of the Moore quarry, in the southeast quarter of the southwest quarter of Section 32, Tp. 2 N., R. 2 W., is the quarry of Mr. W. F. Osborn, which has been opened for about 20 years. The strata exposed here resemble closely those at the Brown Moore quarry. The finished whetstone from some of the layers has a mottled or marbled appearance. The different parts of the layers furnishing this stone vary in the amount of iron and earthy matter contained in them, and consequently in color from a bluish gray to an ash. The arrangement of these varied colored layers into slightly undulating layers gives rise to a marbled appearance in the finished stone by exposing different layers in the same plane. At the old Osborn quarry fossil ferns are abundant in the strata.

In the southwest quarter of the southwest quarter of Sec. 32, Tp. 2 N., R. 2 W., Mr. Gabriel Dougherty has opened up a quarry within the last year or two in which the following section is exposed:

		Feet.	Inches.
1.	Clay and decomposed sandstone	3	
2.	Sandstone	4	6
3.	Shale		18
4.	Sandstone, fine grained, light gray		6
5.	Sandstone, fine grained, in layers 1 and ½ inches thick, worked for whetstone	2	6
6.	Sandstone, fine grained, thin strata, uneven bedded and sharp dipped (worked for whetstone)	2	

Unlike the quarries previously described, in which the strata were horizontal or nearly so, the strata in this quarry show evidence of the presence of strong currents during their deposition. While the upper strata in the above section are nearly horizontal, the lower ones have a very uneven, wave-like bedding. In places in the bottom of the quarry, the whetstone layers bulge upward over a space of 4 or 5 feet and dip off sharply on either side. The worked layers have a dip of about 11 degrees towards the southwest. The stone here makes fair whetstones, but the unevenness of the layers interferes with its working.

At the old Dougherty quarry, in the northeast quarter, Sec. 6, Tp. 1 N., R. 2 W., the following section is exposed:

		Feet.
1.	Clay, residual	2
2.	Sandstone, fine grained, light gray, in layers ½ to 3 inches thick	13

The abundance of fossil Lepidodendra in this quarry has led to its abandonment. A portion of one of these standing upright is exposed which measures 15 inches in diameter. In a portion of this quarry the strata are horizontal, but in the west part they dip 10 to 15 degrees towards the southwest.

In the northwest quarter Sec. 32, Tp. 2 N., R. 2 W., Mr. Wm. Able owns the quarry known as the "Old Red Quarry." The section exposed is:

	Feet.	Inches.
1. Yellow clay	4	
2. Sandstone, fine-grained, in undulating layers, one-half to 3 inches thick	1	6
3. Shale, white, silicious, in layers one-eighth of an inch thick	4	6
4. Sandstone, fine-grained, in layers 3 to 6 inches thick	2	6
Total	12	6

Some of the strata in this quarry are highly colored with iron. Often highly colored, rose tinted bands alternate with paler ones. Sometimes the iron has penetrated the strata laterally from a joint, giving the stone a vertical banded appearance. This quarry has not been worked for several years. In the same quarter-section, just north of the whetstone mill, a small quarry has recently been opened. But little of the stone was exposed when visited. Over most of the northwest quarter of Sec. 32, Tp. 2 N., R. 2 W., the whetstone lies near the surface. It is not overlain by a heavy bed of sandstone as in the neighborhood of most of the quarries.

On Mt. Arie, in the southeast quarter of the southwest quarter of Sec. 28, Tp. 2 N., R. 2 W, northwest of the observatory, Mr. J. E. Buerk has opened a quarry which exposes the following section:

	Feet.	Inches.
1. Clay, residual	7	
2. Sandstone in thin strata	12	
3. Coal	1	6
4. Fire-clay	(?)	
Total	20	6

In the upper part of the bed the whetstone is in layers one-half to two inches thick; they become thicker in the lower part. The strata here have a local dip of twelve degrees to the east. Much of the stone is unevenly bedded.

Orangeville Region.—All of the Hindostan whetstone occurring north of Lost River is included under this heading. The known outcrops and quarries of this region occur along the wide ridge followed by the Vincennes road, and on the two southern projections of it lying on opposite sides of Sam's creek.

The only Hindostan whetstone quarry which has ever been opened in Martin county is in the northwest quarter of the northwest quarter of section 13, township 2 north, range 3 west. This quarry has not been worked for 25 or 30 years and nothing can be seen of the stone except from fragments which have been thrown out. These contain much iron in the shape of minute specks of limonite distributed through the stone and indicate it to be of poor quality.

In the same quarter section as the above mentioned quarry, at the top of the hill on the grade road, is an outcrop exposing about 2½ feet of whetstone. The upper part is in thick layers containing much iron. Worm trails occur in some of the layers. The stone here has a dip of about 13 degrees toward the southwest. This does not represent the general slant of the beds, but is local and the result of the action of currents at the time of their deposition.

A whetstone quarry was opened some years ago about one-quarter of a mile northwest of New Antioch church by Mr. Gabriel Dougherty. But little stone was taken out owing to the thinness of the bed.

It is very probable that good whetstone could be found between Scarlet Chapel and Bond's P. O., along the ridge over which the Vincennes road passes. No quarries have ever been opened along this area and no outcrops of whetstone were seen, but the whetstone bed is doubtless continuous near the summit of the ridge between the Ritter quarry and the quarries to the east of Bond's P. O.

The quarries east of Bond's P. O. occur in sections 23, 24 and 26, township 3 north, range 2 west. The only quarries in this district which are worked at present are those belonging to Mr. J. A. Chaillaux, in the northwest quarter of the northeast quarter of Sec. 23 and the northwest quarter of southeast quarter Sec. 23, township 3 north, range 2 west. At the former quarry the following section was seen:

		Feet.	Inches.
1.	Clay	4	
2.	Shaly sandstone	2	6
3.	Sandstone, heavy bedded		14
4.	Shale		2
5.	Sandstone, heavy bedded	2	
6.	Sandstone, bluish gray in thin layers (whetstone)	3	6
7.	Heavy bedded stone	4	

This quarry is about 200 feet long and averages about 25 feet in width. The stone lies in even-bedded, almost horizontal, layers with smooth surfaces. There is a very slight dip of the bed toward the south.

About a half mile east of this, in the northeast corner of Sec. 23, is a small quarry owned by Samuel Lynn. An opening about 20x25 feet here shows 2½ feet of whetstone. The layers have uneven surfaces and would not work well.

At the old Dishman quarry, in the northwest quarter of southwest quarter Sec. 24, township 3 north, range 2 west, a very large amount of whetstone has been obtained. The quarry is not workable at present.

Stone was formerly shipped from it and manufactured at New Albany. The whetstone bed has here been opened for four or five hundred feet along the brow of the ridge. Fossil ferns are found abundantly at this quarry. At the Marshall Freeman quarry, in the northeast quarter of northeast quarter of Sec. 26, township 3 north, range 2 west, the section exposed is:

		Feet.	Inches.
1.	Clay and soil		20
2.	Shale	2	
3.	Whetstone		12
4.	Shale		8
5.	Sandstone, light gray		14
6.	Shale	2	
7.	Whetstone		20
8.	Shale		16
9.	Sandstone, heavy bedded	4	6

The stone here shows no dip or irregular bedding. It contains much iron oxide in the joints. Dendrites of manganese is frequently seen between the whetstone layers. The manganese and iron give some of the stone a closely specked appearance.

In the southeast quarter of the southwest quarter of section 23, township 3 N., R. 3 W., Mr. G. W. Bedster owns a quarry. This is one of the oldest quarries in the whetstone region, and a large amount of stone has been obtained here in the past; but the quarry has not been worked for a number of years. Most of the layers of stone have a wavy or ripple marked surface; some of the ripple marks in the bottom layers being three to five inches across, and running in a southwesterly and northeasterly direction. Fossil ferns are abundant and a portion of one Lepidodendron trunk was seen in a vertical position.

Palæontology of the Hindostan Beds.—The Hindostan whetstone beds, which were supposed to be barren of fossils at the time of Dr. Owen's visit to the quarries in 1837, have since been found to contain an abundance of fossil plants in an excellent state of preservation in some localities. Of these the Lepidodendra are especially interesting. They are frequently found in the quarries standing upright in the position in which they originally grew, imbedded in the thin, fine grained, sandstone strata. The trunks frequently have the bark transformed to coal, while the interior is a sandstone. The largest specimen seen measured four feet eight inches in circumference. The usual size is six to fifteen inches in diameter.

A series of fossils from the Hindostan beds was submitted to Mr. David White, of the United States National Museum, whose report is given below.

REPORT ON THE FOSSIL PLANTS FROM THE HINDOSTAN WHETSTONE BEDS IN ORANGE COUNTY, INDIANA.

The fossil plants from the Hindostan whetstone beds of Orange county, transmitted by Mr. E. M. Kindle, include nineteen specimens from localities as follows:

Nos. 2, 5 and 8, the Osborn quarry at French Lick.

No. 13, Braxton's quarry, French Lick.

Nos. 16, 17 and 18, from the Bedster quarry.

Nos. 1, 4, 6, 7, 9, 10, 11, 12, 14 and 15, from Dishman's quarry, Sec. 23 (T. 3, N., R. 2 W), near Orangeville. These appear to have been collected by Messrs. Elrod and McIntire.

No. 3 is accompanied by no other geographical information than the name of the county.

The material is nearly all finely preserved and shows well the superficial details. The Lepidodendra are specially interesting, being less compressed than usual.

No. 6, *Sphenopteris hoeninghausii* (Brongn). The specimen appears to represent the form designated by Stur as *Dicksonioides*. It is perhaps only a small example of the former, apparently fertile, the sporangia resembling *Renaultia*.

Nos. 1, 3*a* and 4, *Pseudopecopteris muricata* (Brongn), Lx. The form of the species represented is that common at the Dade mines in Georgia, at various localities in Alabama and in the Horsepen group of West Virginia. I have seen it in other collections from the Indiana whetstone beds. This form differs much from the typical form in Europe, which is much closer to the *Ps. nervosa.*

No. 2 belongs to the same group. It is a small fragment and seems intermediate to *Pseudopecopteris muricata* and the Tennessee form of *Ps dimorpha*, Lx. It is probably nearer the former.

Nos. 3*b* and 7 appear to belong to the Dade, Ga., form of *Neuropteris smithsii*, Lx. It is distinct, however, from the original type of this species, and probably belongs rather to one of the small lateral pinnæ of one of the stratigraphically later phases of *N. biformis*, Lx.

No. 8, which also represents a large form, with rather distant odontopteroid nerves, commonly referred to *Neuropteris smithsii*, is almost certainly a part, a little lower in the frond, of the form next enumerated.

No. 5, *Neuropteris biformis*, the Tennessee form. This form, not uncommon at Rockwood, Tenn., is also found in the Horsepen group on New River, West Virginia. It is much more lax than the original form from Alabama.

The remaining specimens are all *Lepidodendron* of the group represented by *L. veltheimianum* Sternb. It is more than possible that all belong to a single form of the above named species, so remarkably changed are the features of different parts of the same trunk by the accidents of fossilization.

Nos. 11 and 12, *Lepidodendron veltheimianum* Sternb., as commonly seen in this country. In No. 11 the bolsters are truncated at the base as in *L. clypeatum* Lx.

Nos. 13 and 14 are probably the same species, the protruding leaf scars having been compressed towards the upper end of the bolster in fossilization. No. 13 is the form from Dade, Ga., identified by Professor Lesquereux as *L. vestitum* Lx.

No. 9, *L. veltheimianum*, as identified by Professor Lesquereux, from Washington county, Ark., and Tracy City, Tenn. The leaf scar is very large and broadly rhomboidal, the form being extremely close to *L. rhodeanum* Sternb , from the Waldenburg beds in Silesia.

No. 15 is the younger stage of the same form.

Nos. 16, 17 and 18, all fragments of the same trunk, should be compared with *Lepidodendron clypeatum* Lx. It differs, however, from that species by the narrower leaf scars. I suspect it to be merely a phase of *L. veltheimianum*, not uncommon in the upper part of the Horsepen group

The number of species is so small that it is impossible to trace the paleontological equivalence of the Hindostan beds in other portions of the Appalachian coal field with a satisfactory degree of preciseness. Still it is at once apparent that we have here common and typical forms of the Pottsville Conglomerate Series. The species are distributed in the Pottsville from Pennsylvania to Alabama, and are almost exclusively confined to that series. But little attention has been paid in America to the variations of individual species of fossil plants in time, and until these variations, which are of the highest value in stratigraphic paleobotany, have been described and defined, it is necessary to refer to them as phases or forms characteristic of the various stages or regions.

Basing our correlation on such criteria, it appears that the age of the Hindostan whetstone beds can hardly be younger than the Sharon coal of Ohio, the Sewell stage in West Virginia, or the Sewanee stage in Tennessee.

The plants, few as they are, seem rather by their peculiar phases or forms to find a closer relation to the floras of the upper part of the Horsepen group* of West Virginia, the vicinity of the Dade seam in Georgia and Tennessee, or possibly the middle of the Pottsville section in the Southern Anthracite Field of Pennsylvania.

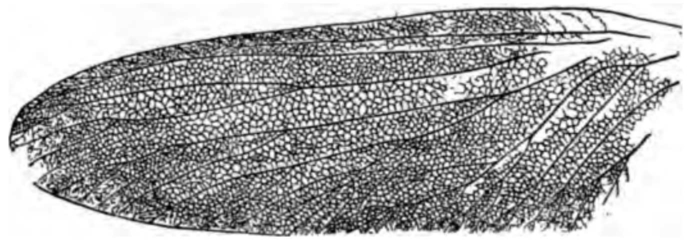
DAVID WHITE.

*See Bull. Geol. Soc. Amer., Vol. VI, 1895, p. 316.

The following species of fossil plants not included in the collection referred to Mr. White have been reported from the Hindostan beds by Prof. Leo Lesquereaux.*

Sphenopteris latifolia.	*Lepidodendron veltheimianum.*
Sphenopteris tridactylites.	*Lepidodendron rushvillense.*
Neuropteris elrodi.	*Lepidophloios crassicaulis.*
Lepidodendron dichotomum.	*Ulodendron minus.*

Paolia vetusta.—S. J. Smith. The insect remains thus far discovered in the whetstone beds are limited to a single specimen, the wing of a Neuropterid insect. This specimen was found in the Braxton quarry near French Lick and presented to the museum of Hanover College. The wing was first described by Mr. S. J. Smith,† whose figure is here reproduced,



as a new genus and new species.

Geological History of the Whetstone Beds.—The shallow sea conditions which existed during the deposition of the sediments constituting the Hindostan beds, doubtless began during the Kaskaskia epoch. The St. Louis formation, lying below the Kaskaskia, is composed of limestones containing a fauna indicating a sea of some depth. In passing to the Kaskaskia a great change in the fossils occurs, and beds of limestone alternate with those of sandstone. Thin coal seams in the Kaskaskia indicate shallow waters, and the presence of cross-bedding in the sandstones points to the existence of both shallow waters and strong currents during their deposition. The cessation of sandstone formation and the renewal of limestone formation, which twice occurred during the Kaskaskia, may have resulted either from the temporary deepening of the sea, the lessening of erosion over the areas whence the sand was derived, or from a change in the direction of the currents which transported it. The sandstones and shales of the lower Mansfield indicate a continuance of shallow ocean waters after the close of the Kaskaskia. The eastern shore line of the carboniferous sea at this time lay not far east of this region. Immediately preceding the deposition of the Hindostan whetstone beds, the ocean became shallow enough over the region to produce

*Coal Flora Penn. Vol. III, p. 852 and Geol. Surv. of Indiana, 1875, p. 7.
†Am. Jour. Sci., Ser. III, Vol. I, pp. 44-46.

marshes in which coal plants grew, and where their remains accumulated and formed the thin coal seam underlying the whetstone bed. The luxuriant carboniferous vegetation overspreading this low lying marsh included, besides several varieties of ferns, jungles of Lepidodendra. The sea marsh condition did not continue long and was followed by a slight depression of the land causing the shore line to shift to the east. The sediments composing the whetstone bed then began to be deposited. We may presume that sedimentation went on rapidly, since we find numerous Lepidodendra standing upright, as they grew, in the whetstone bed. They must therefore have been imbedded in the fine silicious sediments before there was time for them to decay sufficiently to be overthrown by winds or waves.

The very fine sandy sediments, which constitute the whetstone beds, were doubtless derived from the same region of quartzose rocks as supplied the coarse sand of the Mansfield sandstone. The disintegration and erosion of the granite rocks from which the Mansfield sandstone was derived, and its long transportation would necessarily reproduce much fine as well as coarse sand. The difference in the specific gravity of the very fine and comparatively coarse sand grains would lead to their assortment by the water, and cause them to be deposited either in different layers or in different areas. In the assortment and deposition of sediments which gave rise to the whetstone beds, the fine and coarse materials were deposited in different areas. The Hindostan beds therefore represent a local peculiarity of sedimentation, and are the stratigraphic equivalents of beds of very different character to the west of them.

CHAPTER VI.

GRINDSTONE GRITS.

Sandstones which make a good quality of grindstones occur at a number of localities in western Orange, northeastern Dubois and southeastern Martin counties.

DEVELOPMENT.—At present these grindstone grits are not used except locally. A small number are made annually and sold in the local market. Twenty-five years ago grindstones were made somewhat extensively in this region, and numbers of them were sold throughout Indiana and in adjoining States. These stones, which were made entirely by hand, gained for themselves a good reputation in the market. The introduction elsewhere of machinery in the manufacture of grindstones caused those made in Ohio and Michigan to be placed on the market at a lower price than they could be manufactured by hand. This led to the

Ohio stones displacing Indiana stones in the market. On account of a lack of railway facilities for shipping the finished product, the parties owning grindstone quarries in Orange county did not introduce machinery to manufacture the stone. This objection was removed several years ago by the building of the Paoli and French Lick branch of the Monon railroad. There seems to be no reason why the grindstone industry could not be successfully developed in this region by the introduction of the grindstone turning lathe. Such a lathe could be operated in connection with a whetstone mill. An engine used to furnish the power for the rub-wheels could also supply power for a turning lathe.

MANUFACTURE.—It may be well to describe here the process and machinery used in manufacturing grindstone at Berea and Amhurst, Ohio, by the Cleveland Stone Company, which is the largest producer of grindstones in the world. The stone at Berea is quarried in massive blocks by channelers. These blocks are split into slabs the thickness of the desired grindstone. The circular outline of the grindstone is marked on the slab with a scribe awl, and the stone is then broken to a roughly circular outline with a hammer. In this form, which is called the grindstone "pattern," the stone is taken to a factory. Here it is prepared for mounting on the lathe by having a square hole or "eye" picked through the center with a rock pick.

The turning lathe consists of a horizontal steel shaft about three inches in diameter supported by three journals. Near one end a fly wheel connects it by belts with the power shaft. The grindstone pattern is placed on the opposite end and clamped. After the stone is in position a heavy piece of timber, attached to one end of the lathe frame by a hinge, is swung close against the stone, which then hangs vertically between two heavy wooden timbers, the upper sides of which are set with iron pins which serve as braces for the steel bars used in turning the stone. In the process of turning two men stand on opposite sides of the stone, each with a steel bar, the point of which is pressed against the side of the stone inside the rough periphery. The rapidly revolving stone quickly cuts off the rough outer iron against the tips of the steel bars. The face of the stone is leveled up, if rough, by holding the point of the bar lightly against the different parts of it. The process of finishing a stone occupies from one to two minutes.

ADAPTABILITY.—The uses to which grindstones are put cover a wide range. The qualities needed in stones for different purposes are correspondingly different. The character of work which a stone will do depends upon the shape and size of the quartz grains comprising it and the hardness or softness of the stone. To select a stone intelligently, therefore, its coarseness or fineness and degrees of hardness must be considered, as well as the degree of the qualities needed for the work to be done.

Grindstones are used for three purposes: to smooth surfaces, to reduce metal to a given thickness and to sharpen edge tools. A considerable number of grindstones are consumed annually in the manufacture of machinery and implements. For this work a coarse, hard stone is generally best adapted. The Indiana grindstone grit ranges from medium coarseness to very fine. The most of it is soft. It will be found well adapted to grinding carpenters', mechanics' and machinists' tools.

DISTRIBUTION OF GRINDSTONE ROCKS.—Sandstone, having the qualities of good grindstone "grit," is not confined to any one geological horizon. Grindstones have been made from both the lower and upper Kaskaskia sandstones and from the Mansfield sandstones. Neither of these sandstones is suitable for grindstones throughout its extent, but each of them affords good grindstone "grit" at many localities. Only the localities where these grindstones have been made will be mentioned here.

ORANGE COUNTY.—A few grindstones have been made on the land of Wm. Able in the southeast quarter of the southwest quarter Sec. 36, township 3 north, range 2 west. The sandstone here is a light gray color speckled with brown. No grindstones have been made here recently and but little can be seen of the ledge formerly worked. In the northeast quarter of the northwest quarter of section 30, township 3 north, range 2 west, a few grindstones have been made on the land of Mr. W. A. Bruner.

In the northwest quarter of the southeast quarter of Sec. 6, township 2 north, range 2 west, a grindstone quarry is worked occasionally for local use. The stone, which is Upper Kaskaskia sandstone, lies in strata 2½ to 6 inches thick. This stone makes a good fine grained grindstone. About a half mile southeast of Abydel in the southeast quarter of Sec. 30 a ledge of sandstone, most of which is massive and a good building stone, outcrops for about half a mile near the summit of the ridge. The upper part of the bed just east of the road lies in strata 2 to 8 inches thick. These strata are harder than the massive stone and make a good grindstone. Some stones have been made at this locality.

An old grindstone quarry, from which a considerable number of grindstones have been made, is located in the northeast quarter of the northeast quarter of Sec. 15, township 1 north, range 1 west, on the land belonging to the Travelers' Insurance Company. Eniza Wolfington manufactured grindstones at this place twenty years ago and peddled them through Illinois. This quarry is in the Upper Kaskaskia sandstone near the top of the bed. The stone is of medium hardness, and varies in color from nearly pure white to gray and brown with buff. The stone lies in strata three inches to two and one-half feet thick which split readily. One to three feet of stripping is necessary to secure the stone.

On the land of Solomon Lashbrook, in the southeast quarter of the southwest quarter of Sec. 24 (1 N., 2 W.), some grindstones for local use and for coarse whetstones, have been made from the upper portions of the ledge. The stone here splits readily and has a sharp "grit."

An old grindstone quarry on the farm of Benj. Case, in the northwest quarter of the southwest quarter of Sec. 9, (1 N., 2 W.), has yielded more grindstones probably than any other in this region. This quarry was extensively worked about 28 years ago. In 1893, one hundred and fifty grindstones were made from it, but since then it has not been worked. The following section is exposed:

	Feet.	Inches.
Clay and soil..	2	
Sandstone in three to 10-inch layers (grindstone layers)..	15	
Sandstone, containing pieces of carbonized wood and much mica		15
Shale..		10
Sandstone		12

The Upper Kaskaskia limestone outcrops a short distance down the ravine below the above section.

The quarry has been opened for three or four hundred yards along the east side of a ravine which exposes the ledge in places. In front of Mr. Case's house the grindstone ridge becomes massive, but it is said to split readily. A great deal of the stone is a rather fine-grained light-gray sandstone, finely speckled with brown and containing some mica. Another variety is a hard and firmly cemented stone without iron specks. An unlimited quantity of good grindstone grit can be obtained here.

In the southeast quarter of Sec. 1 (Tp. 1 N., R. 2. W.), on the land of David Baxter, a small quarry has recently been opened. The stone lies in layers from 3 to 10 inches thick, quite free from iron concretions and nearly white in color. A few grindstones of excellent quality have been made here for local sale.

In the southwest quarter of the southeast quarter of Sec. 26 (Tp. 1 N., R. 2 W) an outcrop of Upper Kaskaskia sandstone occurs, from which a few grindstones have been made. The lower 6 feet of the outcrop is a hard white, fine grained sandstone. The middle portion is softer and weathers more rapidly than the part above or below it. The upper 10 feet of the ledge is a white, even bedded, easy splitting sandstone which has been used for grindstones with fair success. In the northeast quarter of Sec. 20 (Tp. 1 S , R. 2 W.), on Isaac Kendall's farm, grindstones have been made from sandstone which outcrops on the south bank of Patoka river, near the mouth of Painter creek.

At Newton Stewart the Kaskasia sandstone outcrops in the river bank at the mill. About 15 feet of sandstone is exposed here, which is capped with 4 or 5 feet of clay and soil. The stone is rather coarse grained, white to buff in color, and lies in strata 2 to 15 inches thick. Some grindstones of good quality have been made from it.

DUBOIS COUNTY.—On the land of John Dudine in the northwest quarter of Sec. 14 (Tp. 3 N., R. 4 W.) grindstones have been made for a number of years from sandstone strata 1 to 8 inches in thickness. In the northeast quarter of the northeast quarter of Sec. 21 (Tp. 2 N., R. 4 W.) grindstone "grit" of good quality is said to occur on the bank of White river.

MARTIN COUNTY.—On J. M. Ragan's farm in the northeast quarter of Sec. 8 (Tp. 1 N., R. 3 W) a grindstone quarry has been worked occasionally for local use for the last ten years. About 2½ feet of rough stone and 18 inches of clay and soil lie above the grindstone layers. The stone is light gray and occurs in strata 3 to 8 inches thick. It makes a good rapid cutting grindstone.

The Selfe quarry is located in the southwest quarter of the southwest quarter of Sec. 11 (Tp. 1 N., R. 3 W.). The quarry is in the Mansfield sandstone which here is nearly white and somewhat streaked with buff and brown, rather soft and loosely cemented. About 7 feet of stone are exposed in the quarry. They lie in layers from 1 to 20 inches thick and capped with from 3 to 5 feet of clay. This quarry is worked occasionally to supply grindstones for local use. The stone will make a good rapid cutting, but also rapid wearing grindstone.

CHAPTER VII.

OTHER ECONOMIC RESOURCES.

SANDSTONES—A general account of the sandstones of this region suitable for building purposes will be found in the report of Mr. T. C. Hopkins in this volume. Such notes on outcrops and quarries will be given here as have been made while studying the whetstone and grindstone grits of the region. The position of many of the more important of those outcrops is indicated on the map. (Paoli Sheet.)

DISTRIBUTION OF THE KASKASKIA SANDSTONE.—Two beds of sandstone, separated by the Middle Kaskaskia limestone, which is from 10 to 25 feet thick, occur in the Kaskaskia group. Since there are no marked lithological differences between these two sandstones their outcrops will be considered together. The Kaskaskia sandstone outcrops occur mainly along the water courses, and for this reason they will be taken up in the order of the streams along which they are found.

NORTH SIDE OF LOST RIVER.—Most of the north drainage of Lost River is from small streams three to five miles in length flowing nearly south between high, narrow and crooked regions. The Kaskaskia sandstone outcrops at intervals along each of these streams. The long ridge extending down into the loop of Lost River, which reaches its southernmost extent near West Baden, has much good sandstone in it. On the west side of this ridge, in the southeast quarter of Sec. 15, Tp. 2 N., R. 2 W., a fine ledge of Upper Kaskaskia sandstone, 30 feet thick, is exposed. The stone is light buff to nearly white in color and outcrops at the summit of the ridge where its surface is nearly bare of soil or clay. This bed of stone has been quarried in the southeast quarter of Sec 10 on John Able's land Stone was obtained at this quarry for the abutments of the Lost River bridge near the Miller school house.

In the northwest quarter of Sec. 21, Tp. 2 N., R. 2 W., northwest of the divergence of the present channel of Lost River from the old channel, the Upper Kaskaskia sandstone outcrops in a ledge of good stone 10 feet thick. It is a light buff in color and weathers well.

About a mile and a half down the river from this outcrop, in the southeast quarter of Sec. 16, the Kaskaskia sandstone outcrops near the top of the ridge for a few hundred yards. Much stone has been quarried at this point for local use.

Numerous outcrops of Kaskaskia sandstone occur along either side of Sulphur creek from near its mouth to its source. On the west side of the creek, beginning at Taylor Robin's in the northwest quarter of Sec. 9, the sandstone outcrops nearly continuously for more than half a mile up the creek. Near the head of Sulphur creek, in the north part of Sec. 28, Tp. 3 N , R. 2 W., extensive ledges of good buff sandstone outcrop on both sides of the creek. On the west fork of the same creek in the northwest quarter of Sec. 32, Tp. 3 N., R. 2 W., on the north side of the road, are exposures of sharp gritted, gray sandstone in thin layers. This bed was opened some years ago for the purpose of making scythe stones, but only a few were made.

Sam's Creek.—Three quarters of a mile northwest of the mouth of Sam's Creek, in Sec. 24, the Kaskaskia sandstone is well exposed at Matherson's quarry. The ledge worked here is about 12 feet thick. The stone is gray to buff in color, and stands weathering well. It has been used locally for bridge abutments.

Along the west bank of Lost River, between Sam's creek and Big creek, in the southeast quarter of Sec. 24, a ledge of Kaskaskia sandstone, from 12 to 15 feet thick, outcrops for one-third of a mile near the summit of the ridge. In places this is a soft white stone, but the most of it is a firm buff stone of good quality.

Near the mouth of Buck creek the lower Kaskaskia sandstone forms the bed of Lost River.

Big Creek —The Kaskaskia sandstone outcrops occasionally along the valley of Big creek and the sides of its branches nearly to their sources A quarter of a mile east of Natchez a ledge 18 feet thick outcrops. The lower part of this weathers rapidly, leaving a projecting shelf above. Near the base of this ledge is about 2 feet of coarse conglomerate composed of sandstone pebbles.

The abutments of the bridge across Lost River in the northwest quarter of Sec. 21 (T. 2 N., R. 3 W.) are from Kaskaskia sandstone, outcropping just south of the bridge in the road. Some outcrops of Kaskaskia sandstone occur along the road near this. Below the Butler bridge, in the northwest quarter of Sec. 21, the outcrops of Kaskaskia sandstone are less important. Owing to the southwesterly dip of the strata, the Kaskaskia beds gradually disappear in descending Lost River, until only the upper Kaskaskia limestone is exposed in the river bank a short distance above Windom.

Beaver Creek.—In the northeast quarter of Sec. 2 (Tp. 3 N., R. 2 W.) the Kaskaskia sandstone outcrops for about a quarter of a mile in a ledge 20 to 25 feet thick. Much of the stone here is thin bedded, and of unequal hardness and unsuitable for quarrying. Outcrops of Kaskaskia sandstone occur as far down Beaver creek as Sec. 28, but these are of but little economic importance.

South of Lost River.

Lick Creek.—The channel of Lick creek is cut in the Lost River limestone. The hills and ridges along Lick creek have a more gentle slope than those farther west, and the Kaskaskia sandstones do not crop out so frequently. In the southwest quarter of Sec. 35 (T. 2 N., R. 1 W) a quarry has been opened which supplies most of the stone used for foundation work in Paoli. Two ledges, 6 and 9 feet thick, with 4 feet of stripping, are exposed in the quarry. The stone is light gray to buff in color, and works easily.

Three quarters of a mile southeast of Paoli, just east of the Leavenworth road, stone was obtained for the abutments of the Lick creek bridge at Paoli. The stone here contains much iron and works poorly. In the northeast quarter of the northeast quarter of Sec. 15 (Tp. 1 N., R. 1 W) is an old quarry which formerly furnished a considerable amount of stone for foundations in Paoli. Very good stone can be obtained here with but little stripping.

Sulphur Creek.—In the southeast quarter of Sec. 26, Tp. 2 N., R. 2 W., a ledge of light gray sandstone of fair quality outcrops for several hundred yards along the north side of a ridge facing north. About a half mile south of Abydel a ledge of good sandstone three to eight feet thick outcrops along the north side of a small tributary of Sulphur creek for about a half mile. A small amount of stone has been quarried from it near the road running south from Abydel. This exposure is well situated for quarrying. It lies along the brow of a flat topped ridge, where but little stripping would be required to quarry it.

In the southwest quarter of the southwest quarter of Sec. 5, Tp. 1 N., R. 1 W., a heavy bed of white to buff sandstone, twenty feet thick, outcrops at Painter's Cave. On the east side of the road in the same section good ledges of the same bed outcrop on each side of a small ravine flowing southwest to Sulphur creek.

North of Briner's spring a quarter of a mile, in section 8, a ledge of good stone outcrops on the west side of Sulphur creek. Six feet of light gray to buff sandstone, with moss covered face, is exposed.

French Lick Creek.—A larger amount of good sandstone occurs along the valley of French Lick creek than of any other tributary of Lost River. Uneven outcrops occur along the main stream and all of its tributaries. Along the upper part of the valley much of the sandstone is a white, sharp gritted stone, and is used for whetstones; this stone has been described in the chapter on whetstones.

At West Baden the Upper Kaskaskia sandstone caps the ridges running east from town. A quarry has been opened just east of town. Seven feet of light buff sandstone of very good quality is exposed here with three to four feet of stripping. North of the West Baden Springs hotel a quarry has been opened in the lower Kaskaskia. A bed of massive buff sandstone, 18 feet thick, with 18 inches of stripping, and resting on a bed of black shale is exposed here. This stone contains iron bands and concretions which make it inferior stone.

Good outcrops occur at the following localities: in the northwest quarter of the northeast quarter of Sec. 10, Tp. 1 N., R. 2 W., on the west side of the road; in the southwest quarter of the southeast quarter of Sec. 10, Tp. 1 N., R. 2 W.; in the northwest quarter of section 26, on the west side of the creek; in the southeast quarter of the northwest quarter of Sec. 25, Tp. 1 N., R. 2 W.

Northwest of Mt. Arie.—Two very fine exposures of Kaskaskia sandstone occur in the northwest quarter of section 28 and the southeast quarter of Sec. 20, Tp. 2 N., R. 2 W., on opposite sides of a small stream entering Lost River. On the northwest side of the stream the sandstone forms a vertical cliff of massive sandstone about 30 feet thick, and cut by vertical joints at intervals of 15 to 45 feet. The color of he stone is light buff. The face of the ledge is in places moss covered; in others it shows a pitted honey-comb like surface resulting from irregu-arity of weathering. On the opposite side of the stream in the northwest quarter of section 28, enormous bluffs of massive sandstone, 30 to 40 feet high, extend up either side of a small tributary.

Cave Creek and Buck Creek.—Frequent outcrops of Kaskaskia sandstone are found along each of these streams, but they are not of much economic value. In many places the sandstone is thin bedded and soft.

Patoka River.—The Kaskaskia sandstone outcrops along the sides of the Patoka river as far down as the mouth of Lick Fork creek. At

Centerville and at Newton Stewart the channel of the streams is cut in Kaskaskia sandstone. Between Newton Stewart and Centerville the stream is bordered by lowland; the hills which are neither high nor steep, lie some distance from the river and have comparatively few outcropping ledges.

The most conspicuous outcrop of sandstone along the Patoka is on the north bank, a short distance north of the Government Mill, in Sec. 18, Tp. 1 S., R. 1 W. A bold ledge of light gray sandstone 18 to 25 feet thick outcrops near the top of the ridge. In the southwest quarter of Sec. 11, Tp. 1 S., R. 1 W., on the north side of the river, stone has been obtained for the abutments of the Patoka bridge near by. Five or six feet of good sandstone free from iron is exposed here. Some stone has been quarried for bridge work just east of the road in the northwest quarter of the southeast quarter Sec. 11, Tp. 1 S., R. 1 W. The stone at this place is uneven bedded, splits poorly and contains iron concretions.

Outcrops of Kaskaskia sandstone occur at intervals along the valleys of Painter creek, and Young's creek, which enter the Patoka from the north, from their sources to their mouths.

MANSFIELD SANDSTONE.—The Hindostan whetstone beds, which are economically the most important part of the Mansfield sandstones, have already been described. Over the southeastern part of the region covered by the map, the Mansfield sandstone is represented by a thin bed of sandstone, much impregnated with iron, capping the summits of the narrow ridges. It is of no economic value in this region.

Toward the west the Mansfield beds become thicker and finally in northeastern Dubois county entirely replace the Kaskaskia which dips southwest and disappears under the Mansfield sandstone.

SOUTH OF PATOKA RIVER.—The Mansfield sandstone forms numerous vertical cliffs twenty to eighty feet high at the heads and along the sides of the deep ravines south and west of Ellsworth. One of these cliffs, in the northwest quarter of Sec. 16, Tp. 1 S., R. 3 W., is called Raven Rock. Ravens are said to have nested on the inaccessible shelves of this cliff as recently as three years ago.

This cliff is about 75 feet high, shelving out from the base to the top, which projects about 35 feet beyond the base. The rock is massive, dark buff to brownish in color, composed of coarse, loosely cemented sand with some mica. The lower part of the ledge is characterized by numerous thin, wavy bands of iron ore running through the ledge in a most intricate fashion. The loosely cemented character of this stone makes it unsuitable for economic uses.

There are some ledges in this region, however, which furnish good quarry stone. On the land of Benjamin Rasche, in the northwest quarter of Sec. 6, Tp. 1 S., R. 3 W., a quarry has been opened. The stone here is a light gray, easy working stone. From it stone is used for foundation work in Knoxville. In Sec. 4, Tp. 1 S., R. 3 W., stone has been quarried near the Patoka bridge for the abutments.

BETWEEN PATOKA AND LOST RIVERS.—At several localities along Dillon and Davis creeks, the Mansfield sandstone occurs as a finely cemented, light buff or gray sandstone, suitable for building purposes. At "Swinging Rock," near the line between Sections 33 and 34, Tp. 1 N., R. 3 W., on the north side of Cave creek, a cliff of sandstone about 35 feet high is exposed. The stone is a light gray, fine grained, and in strata two to three inches thick. This stone is locally used for chimneys.

About a quarter of a mile west of the school house in the northeast quarter of Sec. 34, Tp. 1 N., R. 3 W., a ledge of sandstone 25 feet thick outcrops just above the Upper Kaskaskia limestone. The upper six feet of this is good stone, the lower portion being soft. A conspicuous outcrop of sandstone about 20 feet high occurs on the south bank of Dillon creek in the southwest quarter of the northeast quarter of Sec. 35, Tp. 1 N., R. 3 W. The sandstone here contains too much iron to be of value. In the southwest quarter of Sec. 24, Tp. 1 N., R. 3 W., a ledge of sandstone from six to 20 feet thick, resting on the Upper Kaskaskia limestone, outcrops along the north and east side of the road for some distance. The stone in places is soft and crumbling, and in others contains too much iron to be of value. In the northeast quarter of the southeast quarter of Sec. 19, Tp. 1 N., R. 2 W., a quarry has been opened on Jeff Parson's land, which supplies stone for chimneys and other local uses. The stone is a handsome light gray, fine grained, hard stone. An excellent quality of stone is quarried for local use on Richard Spaulding's land in the northeast quarter of the southeast quarter of Sec. 21, Tp. 1 N., R. 2 W. This is a light gray, fine grained, hard stone, containing some mica. It splits readily. The worked stone is about five feet thick with four feet of stripping.

Prominent ledges of sandstone outcrop just north of Crystal, and along the sides of the branch entering Davis creek from the south at that point. A ledge of good light colored sandstone outcrops near the corners of Sections 7, 8, 17 and 18, Tp. 1 N., R. 3 W., on the west side of the road. The ledge here is eight feet thick with moss covered face. At most of the outcrops along Simmon's creek and its branches, the sandstone is loosely cemented and crumbles too easily for a building stone.

In the northwest quarter of Sec. 17, Tp. 1 N., R. 2 W., at Sand Hill, the Mansfield sandstone is locally colored, a dark reddish brown. Stone of this color outcrops in the road at the top of the hill, where it exhibits marked cross bedding. Just south of the road the red sandstone again outcrops in a ledge seven feet thick. The ledge here presents a firm moss covered face. A short distance to the southeast of the ledge, and somewhat lower, the red sandstone becomes soft and crumbling.

On the north side of the road the red stone becomes buff or gray in a distance of a few hundred yards. The area underlaid by red sandstone suitable for working is very limited, not exceeding a few hundred feet square. On the east side of the hill, in the road, the sandstone crumbles readily to sand, which is used in some of the whetstone mills.

Another small exposure of red sandstone occurs on the north side of the road, in the southeast quarter of the southeast quarter of Sec. 31, Tp. 2 N., R. 2 W. The stone here is composed of coarse sand with much mica, and is a pale red to chocolate brown. The red stone is almost bare of soil, and covers not more than a quarter of an acre.

North of Lost River.—The Mansfield sandstone outcrops frequently near the summit of the ridges north of Lost river, but it is not generally a good quarry stone. Extensive and conspicuous cliffs of Mansfield sandstone occur along the White river near Shoals, and along Plasterer's creek. The stone at these localities is unsuitable, however, for economic uses, since it is too loosely cemented to resist the weathering. A ledge of very good stone has been opened a half mile southeast of Shoals in the southwest quarter of the southeast quarter of Sec. 30, Tp. 3 N., R. 3 W. Stone has been obtained here for the basement of the High School building in Shoals. Ten feet of stone, with two to five feet of stripping, is exposed in the quarry. The stone is light gray, rather fine grained, and lies in strata three to five feet thick.

Stone has also been quarried in the northwest quarter of Sec. 32, Tp. 3 N., R 3 W.

Limestones.—The three limestone members of the Kaskaskia group in this region exhibit most of the lithologic features possible to limestones. The lowest of these, the Lower Kaskaskia limestone, is generally a very compact, close textured, uncrystalline limestone.

"Glass Rock."—Where this stone is quite pure and light gray in color, it makes an excellent limestone for the manufacture of glass. It has been largely used for this purpose. At many localities along the upper valley of Lost river, and along Lick creek the limestone is suitable for glass making and has been quarried for this purpose. At Glass Rock station, on the French Lick branch of the Monon, the stone is quarried and shipped.

Lime.—The Middle and Upper Kaskaskia limestones, as well as the Lost River limestone, have been used for the manufacture of lime. Kilns were formerly burned near Lost River and the lime shipped down to New Orleans in flat boats. In many places the upper and middle Kaskaskia limestone have an oölitic structure. This kind of limestone is said to make particularly good lime. At a few localities lime is burned at present and used for a fertilizer on sandstone soils.

Marble.—Throughout much of its extent the Upper Kaskaskia limestone is a light gray crystalline stone. The Middle Kaskaskia limestone also has a crystalline structure in many localities. Both of these stones, in some localities, will take a fair polish and make a nice looking marble.

A quarry has recently been opened in the Middle Kaskaskia limestone by Mr. Lowe in the northeast quarter of the northwest quarter of Sec. 17 (Tp. 1 S., R. 1 W.). This quarry is located in a ravine where a large amount of stripping must be removed in quarrying the stone. About 8 feet of stone is exposed in the quarry, lying in strata 6 to 14 inches thick. This lower part of the bed is a lead blue, compact, imperfectly crystalline stone. The upper part is a gray, crystalline limestone which takes a fair polish. The Upper Kaskaskia limestone, which outcrops where the quarry could be more easily worked, would probably make a better marble. A few tombstones have been made from the marble quarried here. Much of the Upper Kaskaskia limestone will take a good polish and make a marble of pleasing appearance. The badly weathered and cracked condition of the ledges in many places indicate, however, that much of it will make a marble which can not resist the destructive influences of freezing and thawing.

The position and extent of the Upper Kaskaskia limestone is sufficiently indicated on the map. All of its outcrops occur at or near the line separating the Kaskaskia from the Mansfield sandstone.

COAL.—The location of all the coal mines in the region mapped has been indicated on the map. Since it is the intention of the State Geologist to publish a special report on the coal of the State, no discussion of the coal of this region will be attempted here.

ACKNOWLEDGMENTS.—The survey is indebted to Mr. David White of the National Museum for the report on fossil plants which he kindly furnished.

To Mr. T. C. Hopkins I am indebted for many valuable suggestions in the preparation of the map.

Acknowledgments are also due to Prof. G. D. Harris, and Prof. A. C. Gill, of Cornell University, for favors received during the preparation of the report.

Without exception, I have received the hearty co-operation of the quarrymen.

During the field work I have been under obligations to very many of the citizens for assistance of various kinds. My thanks are especially due to Mr. Russell Ratliff, Mr. Chas. Spalding and Mr. Harvey Chairnes.

REPORT OF THE STATE NATURAL GAS SUPERVISOR.

LETTER OF TRANSMITTAL.

OFFICE OF NATURAL GAS SUPERVISOR,
KOKOMO, IND., Jan. 13, 1896.

SIR—I herewith transmit to you my first annual report upon the condition of the natural gas field of Indiana. It is made in obedience to Section 7504 of the Revised Statutes of the State of Indiana, and covers the period from March 16, 1895, to January 1, 1896.

Owing to the short time that I have had charge of this office and the amount of time that it has been necessary for me to spend in the field, it has not been possible for me to make this report as comprehensive as I would like. Now that I am acquainted with the field, I hope that my next report will more nearly represent the magnitude and importance of the Indiana natural gas field.

Believing that the field work of this office is most important, I have spent a large part of my time inspecting gas property. The safety of life and property requires all gas mains, pipes, regulators, etc., to be kept in good condition. Much of the piping and machinery in use at present is old and worn, and the necessity for a careful inspection of the same is apparent. It has not been possible, to the present time, for me to visit the entire field, but my work has been systematic, and I hope soon to report the condition of every gas plant.

Wherever I have been, the owners and managers of gas plants have expressed a willingness to give me all the aid and information possible, thereby making my work pleasant and I trust profitable to the gas interests of the State.

I take pleasure in acknowledging here, the cordial support that I have received from you. Your helpful suggestions and kind aid and encouragement are appreciated.

I respectfully submit this report and remain,

Yours sincerely,

J. C. LEACH,
State Natural Gas Supervisor.

PROF. W. S. BLATCHLEY,
State Geologist.

INTRODUCTION.

The reports from this Department, to be of value, should contain such information as the public desires to know, and discuss such subjects as demand the attention of those who are interested in the natural gas industry of Indiana. They should contain an accurate history of the gas field; a history in which all phases of the subject have been discussed, and in which the condition of the field has been noted from year to year.

In compiling this, my first annual report, I have tried to keep in view its purpose, but of necessity have had to submit to some limitations. The law authorizing an annual report from this division of the Department of Geology and Natural Resources to the State Geologist defines to some extent the nature of the report. The duties of the Natural Gas Supervisor, as defined by law, are not arranged with reference to the compilation of a report, but with sole reference to the needs of the gas industry. This is right. The most important work of the Supervisor is not the making of an annual report, but is the performing of the duties in the field as the law specifies. I would not be understood as underestimating the value of any report in which the scientific or commercial world are interested. The exhaustive reports made by the Departments of Geology of both Pennsylvania and Ohio on the natural gas regions of those States have been of great value to geologists in Indiana, and in fact to every one interested in the natural gas industry. I only wish it were possible for me to compile a report as comprehensive as the subject demands, and one that would fairly represent the magnitude of the Indiana gas field. Taking into consideration the area of the Indiana gas field, and the amount of time that must necessarily be given to the field work, it will be seen at once that an annual report from this office can be little more than a record of the field work.

During the early history of the Indiana field, questions relating to the economic use of gas did not receive much attention. Most people believed that nature had provided for a renewal of the supply. Why give any time to this phase of the question, when the supply was inexhaustible? It was during this period that the scientific phase of the question received most attention. The discussion of the subject was not confined to geologists and chemists alone. Many who did not profess a knowledge of these sciences were able, as they thought, to account for the origin of this new fuel. It was but natural that those who witnessed the power exerted by this gaseous fuel, as it rushed forth from its rocky prison, or who were permitted to enjoy the luxury of its power, when re-imprisoned, should look for a cause for this new phenomenon. But few were able to account for the origin of gas or its pressure, but many reached the happy conclusion that its life would be equal to all time. This, to the geologist, was not the logical conclusion; a conclusion that the facts involved would substantiate He claimed that the stock of gas was practically complete; that when once exhausted, there was no provision in nature for its renewal. Experience to date indicates that this is true. If the public mind had been in accord with this idea at the beginning, as it is now, the benefit derived from natural gas in this field would have far exceeded what it has been; for the idea that the supply of gas was good for all time, either by virtue of the enormous amount stored in the rocks, or a provision of nature for the renewal of the present supply, has, to a large degree, been the cause of the extravagant use of gas that has been practiced in the Indiana gas field. Public opinion, however, has changed. The history of other gas fields is finished, and the present condition of the Indiana field indicates that the history of it will be a repetition of the history of every other field.

While the scientific phases of the natural gas question will always be subjects of thought, we have reached that period in the history of the Indiana field when economic measures are of most interest. Methods of economy are more interesting than modes of origin. Instead of spending time and energy inventing and arranging apparatus, by means of which the gas from one or more wells can be made to illuminate the country for miles around, the owners of gas property are interested in scientific burners and devices, invented to protect gas wells and territory, and husband the supply of gas. It is not as difficult to convince the extravagant consumer of gas that the rock pressure is going down; that the salt water is becoming intrusive and that the supply of this new fuel will soon be exhausted, as it once was. The evidence is more convincing now. Statements concerning the gas supply, once labeled as idle assertions made in the interests of gas companies, are now recognized as facts. Any effort to husband the supply of this gaseous fuel meets the public's approval; and while there are but few, comparatively speaking, who practice economy in the use of gas, an examination will reveal the fact that the cause does not lie in the will of the consumer to waste gas, but rather in the kind and arrangement of the devices used in the combustion of this gaseous fuel. The public favors economy in the use of gas. It is late to begin, but not too late. Natural gas is valuable property and a business like economy practiced in the use of it will, even at this late day, materially extend its life.

Questions relating to the origin of rock oil and gas have been discussed by the scientific world for a number of years. Much has been said and many theories advanced. I will not attempt to discuss the many theories that have been proposed to account for the origin, accumulation, or pressure of this hydrocarbon, or to advance any new theory concerning the same; but, inasmuch as the theoretical views that we hold regarding the subject will influence our judgment as to the supply, I have thought it proper, in a subsequent chapter, to give brief statements of the views most commonly accepted as to the origin and accumulation of natural gas.

The present condition of the Indiana gas field is a matter that interests a large number of people, and a subsequent chapter will be devoted to this subject.

In regard to scientific devices and economic methods of using gas, much investigation has been made during the past year. Especially is this true of manufacturers and gas companies. All realize that natural gas is most valuable as a heating power, and how to get the maximum power from the minimum amount of gas, consistent with the work done, is the question. Upon this subject Prof. Elwood Haynes, of Kokomo, Indiana, has, at my request, prepared a paper for this report. Prof. Haynes is an expert chemist, as well as a natural gas engineer of large experience. He is constantly experimenting along the line of natural gas economy, and his paper will be read with interest, especially by those acquainted with his work in the Indiana gas field.

The past year has witnessed some anxiety and much speculation, on the part of the gas consumer, regarding the schedule of rates for the future. This has not been without cause. In some cities the rates have been materially advanced, while in others there has been much talk and nothing done. Many inquiries come to this office regarding the rates charged in the different cities of the gas belt. Owing to the numerous provisions in the schedules of the various cities using gas, it has not been practical to tabulate them for this report. Those desiring information can obtain it by addressing the gas companies of the State, a list of which is given in this report.

With former reports from this Department, a map of the natural gas area has been given. This has proven very convenient, especially to those who desire to become acquainted with the gas field. I have exerted much care in preparing the map that accompanies this report, and believe it to be practically correct. The outline of the natural gas area is substantially the same as that given on former maps, and is aimed to include all territory that has produced gas in commercially valuable quantities. The pipe lines are located in accordance with maps furnished by the different gas companies, and include all extensions to December 1, 1895. On account of the size of the map, pipe lines tributary to the main lines are not given, and for the same reason it has been impossible, even if desirable, to indicate the location of all the gas wells. Those indicated are but a small per cent. of the total number, but the ratio is intended to be uniform.

Though frequent reference is made to the natural gas law of the State, but few are acquainted with its provisions. The law consists of what may be termed a general law, defining the duties of the Natural Gas Supervisor, and certain special laws enacted to protect the natural gas industry of the State. Its provisions are comprehensive, and it is the duty of the Natural Gas Supervisor to see that they are enforced. But, notwithstanding this, and however broad the law may seem or however ample the authority of the Supervisor may appear, there have been some instances of gross negligence on the part of gas companies and consumers, and flagrant waste by both, that no reasonable construction of the law could prevent. In cases like these, the Supervisor is usually accused of neglecting his duty. In order that those who desire to become acquainted with the law may have the opportunity, and because I believe that the work of this office will become more effective as the public becomes more familiar with its provisions, I have had it printed in a convenient form for general distribution, and will gladly mail one or more copies to those desiring it.

ACKNOWLEDGMENTS.

I take this opportunity to express my indebtedness to all who have rendered me assistance in my work. Without the help that I have received from the officers of the different gas companies, from manufacturers and drillers, my duties would have been much more arduous.

NATURAL GAS.

Its History, Composition, Fuel Value, Origin, Accumulation, Pressure and Measurement.

EARLY HISTORY.

The fact that an inflammable gas escapes more or less freely in every country, from the bottom of ponds and shallow lakes, stagnant water of swamps, springs and crevices in the earth, has been known for a long time. It is frequently found in excavations in recent deposits at the mouths of rivers, and, in fact, wherever the deposit contains organic matter this marsh gas, as it is called, will be found; for the principal conditions upon which its generation depends are a deposit of organic matter and temperature, together with the exclusion of the air from the decaying substance. This gas is being constantly generated, and there is no doubt but that enormous quantities escape into the atmosphere. It is a compound of carbon and hydrogen, and is the principal constituent of natural gas.

The history of natural gas would require a volume. It has been found in nearly every country and geologic formation. Its presence was known and its power utilized to some extent in China, Japan and in the vicinity of the oil regions near the Caspian Sea many years ago. In China the gas escapes from the borings put down for salt water, and is utilized in boiling down the brine. As might be expected, the tools used in sinking these salt water wells are very crude, and the process of drilling very slow. The wells are cased with wood and the gas transported to the evaporating pans in bamboo pipes. Clay burners are used.

The small quantities of natural gas found in the vicinity of the oil fields of Japan have never been utilized to any extent.

The village of Fredonia, Chautauqua County, New York, used natural gas for illuminating purposes as early as 1821. As far as can be ascertained, this was the first use of natural gas in this country. In 1841 natural gas was used to boil the brine from the salt wells in the Kanawha Valley, West Virginia. A gas well 1,000 feet deep was drilled near the same place in 1843. This well produced "high-pressure" gas, and is the first of its kind on record.

The history of the natural gas industry in Pennsylvania probably dates from the beginning of the drilling for oil in 1859. More or less gas usually accompanied the oil, and at first was allowed to escape into the atmosphere without notice, but later was piped a safe distance from the well and burned. After awhile it was used as fuel under the boilers in drilling and pumping. Natural gas began to be used extensively as a fuel in 1883. It was then that the gas from the Murrysville district was piped to Pittsburgh.

As soon as gas began to be used extensively for manufacturing and domestic purposes in Pennsylvania and its value as a fuel became known, explorations began and have continued ever since. There are but very few States in the Union in which the drill has not penetrated the underlying rocks in search of this gaseous fuel.

In 1884 gas was discovered in the Trenton limestone at Findlay, Ohio. This gave a new impetus to the gas industry. Prior to this time valuable deposits of natural gas had been found in sandstones only; now that a new horizon had been discovered, those whose efforts heretofore had ended in failure took courage. Companies were organized and the drill was sent on its journey of exploration in many localities. In 1886 this limestone was found to be a gas-producing rock in Indiana. The result of this discovery is familiar to a majority of those for whom this report was written. The subject will be mentioned in a subsequent chapter.

Natural gas has been found in a number of States besides those above mentioned. However, outside of Pennsylvania, Ohio and Indiana the supply has not proven very valuable. According to the United States Geological Survey the combined value of the natural gas produced in the United States outside of these three States does not equal one-half the value of the production of either one of these States. It is impossible to calculate the actual value of the natural gas consumed in the State of Indiana during the year 1895, or any previous year.

An approximate value can be given only, and this is very unsatisfactory, from the fact that in many instances it is impossible to obtain the amount or value of the gas used. The volume of Mineral Resources of the United States, 1893, published by the United States Geological Survey, gives a table in which an estimate of the value of the natural gas consumed in the United States from 1885 to 1893 is given. While it can not be claimed that the statements given in this table are more than approximately correct, the author, Mr. Joseph D. Weeks, has used every available means to obtain correct estimates. The basis of the calculations in this table is the value of the fuel displaced by natural gas. Assuming that the statements made are only approximate, a comparison of the various amounts given is interesting. For the benefit of those who have not access to this volume of the Mineral Resources, the table above mentioned is given here.

VALUE OF NATURAL GAS CONSUMED IN THE UNITED STATES, 1885 TO 1893.

Localities.	1885.	1886.	1887.	1888.	1889.
Pennsylvania	$4,500,000	$9,000,000	$13,749,500	$19,282,375	$11,593,989
New York	196,000	210,000	333,000	332,500	530,026
Ohio	100,000	400,000	1,000,000	1,500,000	5,215,669
West Virginia	40,000	60,000	120,000	120,000	12,000
Indiana	....	300,000	600,000	1,320,000	2,075,702
Illinois	1,200	4,000	....	....	10,615
Kentucky	....	....	....	....	2,580
Kansas	....	6,000	....	....	15,873
Michigan	....	12,000	....	....	....
Missouri	....	....	....	....	35,687
Arkansas	....	....	....	....	375
Texas	....	....	....	....	1,728
Utah	....	....	....	....	150
South Dakota	....	....	....	....	25
California	....	....	....	....	12,680
Elsewhere	20,000	20,000	15,000	15,000	1,000,000
Total	$4,857,200	$10,012,000	$15,817,500	$22,629,875	$21,107,099

VALUE OF NATURAL GAS CONSUMED IN THE UNITED STATES, 1885 TO 1893.—Continued.

LOCALITIES.	1890.	1891.	1892.	1893.
Pennsylvania	$9,551,025	$7,834,016	$7,367,281	$6,488,000
New York	552,000	280,000	216,000	210,000
Ohio	4,684,300	3,076,325	2,136,000	1,510,000
West Virginia	5,400	35,000	500	123,000
Indiana	2,302,500	3,942,500	4,716,000	5,718,000
Illinois	6,000	6,000	12,988	14,000
Kentucky	30,000	38,993	43,175	68,500
Kansas	12,000	3,500	40,795	50,000
Michigan	....	....	....	....
Missouri	10,500	1,500	3,775	2,100
Arkansas }	6,000	250	100	100
Texas }		{	100	50
Utah }		{	....	500
South Dakota }		{	....	....
California	33,000	30,000	55,000	62,000
Elsewhere	1,600,000	250,000	200,000	100,000
Total	$18,792,725	$15,500,084	$14,800,714	$14,346,250

COMPOSITION.

Natural gas is one of a series of the products of the earth's crust, known as bitumens; naptha, petroleum, maltha, asphaltum, etc , belong to the same list, are found under substantially the same conditions, and doubtless have the same history, consequently whatever is said of natural gas can be applied with equal propriety to petroleum.

Although natural gas is used for lighting purposes to some extent, its chief value is in its heating power. This depends upon its chemic composition, and any change will effect this power. It has not been convenient to analyze a sample of Indiana gas for this report, but a number of analyses of Ohio and Indiana gas, given by Prof. Orton in the Eighth Annual Report of the United States Geological Survey, are used here. They were made in July, 1887, by Prof. C. C. Howard, of Starling Medical College, Columbus, Ohio.

COMPOSITION OF TRENTON LIMESTONE GAS. (Howard.)

CONSTITUENTS.	OHIO.			INDIANA.			
	Fostoria.	Findlay.	St. Mary's.	Muncie.	Anderson.	Kokomo.	Marion.
Hydrogen	1.89	1.64	1.74	2.35	1.86	1.42	1.20
Marsh gas	92.84	93.55	93.85	92.67	93.07	94.16	93.58
Olefiant gas	.20	.35	.20	.25	.49	.30	.15
Carbon monoxide	.55	.41	.44	.45	.73	.55	.60
Carbon dioxide	.20	.25	.23	.25	.26	.29	.30
Oxygen	.35	.39	.35	.35	.42	.30	.55
Nitrogen	3.82	3.41	2.98	3.53	3.02	2.80	3.42
Hydrogen sulphide	.15	.20	.21	.15	.15	.18	.20
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

NOTE.—The Fostoria gas was taken from the Watertanks wells; the Findlay gas from the six wells of the Findlay Gaslight Company; the St. Mary's gas from the Wilkins well; the Muncie (Ind.) gas from Wells Nos. 1, 2, 3, 4 and 6; the Anderson gas from the McCullough well; the Kokomo gas from wells Nos. 1 and 2, and the Marion gas from well No. 3.

An examination of the analyses given above will not only show that the composition of Trenton limestone gas from all parts of the field is practically the same, but its constancy is remarkable as well. Samples of this gas from wells varying in depth and pressure, and from the same well, taken at intervals of several weeks, have been analyzed with the same results. Not a single objectionable element is found in it, with the possible exception of the small percentage of hydrogen sulphide, and this is not really objectionable, from the fact that its odor discloses any leakage or dangerous accumulation of gas that may be in or about the premises.

I have given the analyses of samples of gas from both Indiana and Ohio, and for the benefit of those interested in the natural gas industry who have not access to the reports of the Pennsylvania Geological Survey, I add a table in which the composition of a number of samples of Pennsylvania gas is given. These analyses were made by F. C. Phillips, Professor of Chemistry, Western University, Allegheny, Pa., and were published in the Annual Report of the Pennsylvania Geological Survey, 1886.

COMPOSITION OF PENNSYLVANIA NATURAL GAS. (Phillips.)

CONSTITUENTS.	Sheffield.	Wilcox.	Speechley.	Murrysville.	Baden.	Houston.
Nitrogen	9.06	9.41	4.51	2.02	12.32	15.30
Carbon dioxide	.30	.21	.05	.20	.41	.44
Hydrogen	......	......	.02	......	......	......
Ammonia	......	......	......	......	......	trace
Oxygen	trace	trace	trace	trace	trace	trace
Sulphuretted hydrogen	......	......	......	......	......	......
Paraffin	90.64	90.38	95.42	97.70	87.27	84.26
	100.00	100.00	100.00	100.00	100.00	100.00

The paraffins contained in the samples given above have the following composition by weight:

	Sheffield.	Wilcox.	Speechley.	Murrysville.	Baden.	Houston.
Carbon	76.69	76.52	77.11	74.96	76.48	76.68
Hydrogen	23.31	23.48	22.89	25.04	23.52	23.32
	100.00	100.00	100.00	100.00	100.00	100.00

In the Pennsylvania gas it will be observed that there is a notable variation in the proportion of the constituents of the gas from the different fields. The amount of nitrogen varies between 2.02 per cent. and 15 30 per cent., and the paraffins between 84.26 per cent. and 97.70 per cent.

The proportion of carbon to hydrogen in the paraffins also varies, the Speechley gas being richest in carbon. Of sulphuretted hydrogen, a universal element of Trenton limestone gas, there is not a trace found in this gas.

The principal constituent of natural gas is marsh gas or methane (CH_4), a type of a series of hydrocarbons, sometimes called the paraffin series. It burns in the air with a pale, almost non-luminous flame, and when mixed with oxygen explodes violently on the application of a flame or the passage of an electric spark. Perfect combustion of methane requires about ten times its volume of air. This fact should be remembered by the consumer of natural gas, and arrangements should be made to admit the proper amount of air. In the consumption of gas, combustion will be incomplete and the power of the fuel lost in part if it is not mixed with air in the proper proportion. According to Prof. Phillips, marsh gas will be reduced to a liquid under a pressure of 2,700 pounds per square inch at 12° F., or 263° below zero F., under atmospheric pressure. It will be observed that this is over eight times the pressure found in the most productive gas wells in this field.

Hydrogen, a small per cent. of which is found in its free state in natural gas, is a colorless gas, and when pure has neither taste nor smell. It is combustible and the product of its combustion is water. It is 14.44 times lighter than air and is very diffusible.

Olefiant gas or ethelene (C_2H_4) is a heavy carburetted hydrogen, produced when substances rich in carbon and hydrogen are decomposed by dry distillation. It is a colorless gas, having very little odor and can be condensed to a liquid.

Carbon monoxide (CO) is formed when a carbonaceous substance is burned in a stove or furnace in which the supply of air is not sufficient. It burns with a pale blue flame and is very poisonous when inhaled.

Carbon dioxide (CO_2), the principal compound of carbon and oxygen, is a colorless gas and has a feeble odor. It is found in many natural processes, is always present in the air and soil, and is a universal product of combustion and decay. It is frequently found in old wells and mines and is largely the food of plant life. While it is not poisonous, animals die of suffocation when compelled to breathe it. Carbon dioxide is heavier than air, and for the reason that it holds in combination all the oxygen possible, it is incombustible. Trenton limestone natural gas contains but little more than a trace of this gas.

Oxygen, a tasteless, inodorous, invisible gas, minute traces of which are found in natural gas, is the most widely distributed gas known. It combines with most of the other elements, resulting in the phenomenon of combustion.

Nitrogen, a well known element of natural gas, constitutes about four-fifths of the atmosphere. It does not support combustion and is a dilutent of marked influence, thereby reducing the calorific or heat producing power of the gas. Nitrogen is colorless, tasteless, without odor and somewhat lighter than air. It will not support breathing, animals becoming quickly suffocated in an atmosphere of this gas, not on account of its poisonous influence, but from a lack of oxygen.

Hydrogen sulphide (H_2S), known as sulphuretted hydrogen, is a colorless gas, having a penetrating, disagreeable odor. It is formed by the decomposition of organic substances containing sulphur, or by the heating of the same, and is poisonous when inhaled in large quantities for any length of time. Hydrogen sulphide is combustible, and when mixed with one and one-half times its volume of oxygen, will explode upon the application of a flame or the passing of an electric spark.

I have given above a brief description of the chemical constituents of Trenton limestone gas. If it serves to impress upon the consumer the fact that this gaseous fuel contains elements of great danger to life and property, in many ways and under many conditions, and thereby causes him to exercise a due amount of care, not only in supplying safety devices and in the arrangement of burners and mixers, but in the use of gas in general, it will have served its purpose.

FUEL VALUE OF NATURAL GAS.

As I have said, the great value of natural gas lies in its heating power. It possesses many advantages over wood and coal, both for domestic and manufacturing purposes. Whether it be cheaper or not, it is more convenient, and for many kinds of manufacturing it is, on account of the superior quality of the manufactured product, pre-eminently the best fuel.

In volume 6 of the Reports of the Ohio Geological Survey, Prof. Orton gives a comparison between the fuel value of Pittsburgh coal and Pittsburgh and Findlay gas. The data used by Prof. Orton were prepared by Prof. Lesley, of the Pennsylvania Geographical Survey, Mr. S. A. Ford, chemist of the Edgar Steel Works, Pa., and Prof. C. C. Howard. Inasmuch as Indiana and Findlay gas have practically the same composition, this comparison is germane, and is given in this report.

According to the statements referred to above, the theoretical value of 1,000 cubic feet of Pittsburgh gas, weighing thirty-eight pounds avordupois, is 210,069,604 heat units. The theoretical value of thirty-eight pounds of pure carbon is 139,398,869 heat units. On the basis of these figures, the heat units of 1,000 cubic feet of gas will be found to equal 57.25 pounds of carbon; 67.97 pounds of coke; 54.40 pounds of bituminous coal, or 58.40 pounds of anthracite coal. Now, according to these figures, if coke is worth $2.50 per ton, the fuel value of 1,000 cubic feet of Pittsburgh gas is 7.8 cents, and if Pittsburgh coal is worth $1.25 per ton, the fuel value of 1,000 cubic feet of Pittsburgh gas is 3.25 cents. One ton of Pittsburgh coal is theoretically equal to 36,764 cubic feet of Pittsburgh gas.

The theoretical value of 1,000 feet of Findlay gas is 228,461,113 heat units, and when Pittsburgh coal is worth $1.25 per ton the theoretical value of 1,000 feet of Findlay gas is 3.9 cents. One ton of Pittsburgh coal is theoretically equal to 31,085 cubic feet of Findlay gas.

In referring to the above comparisons, Prof. Orton says: "In the preceding calculations it will be observed that the theoretical values only are discussed. The practical advantage in the use of gas is much greater than the figures above given would lead one to suspect. In burning coal, a large part of the possible heat is lost in various ways. In burning gas there is a much greater economy of heat. Theoretically one pound of Pittsburgh coal is equal to 18⅓ feet of Pittsburgh gas, but it has been determined by carefully conducted experiments that seven and one-half feet of gas are practically equal to one pound of coal. Findlay gas will give somewhat better results than this. Less than seven cubic feet of gas will do the work of one pound of Pittsburgh coal, or less than 14,000 cubic feet of gas are practically equal to one ton of Pittsburgh coal. Trenton limestone gas is thus seen to be one of the most valuable fuels known to man. The reckless use, and especially the wanton waste of it, are little more than a crime against the State."*

What Prof. Orton says regarding the Ohio gas field is equally applicable to the Indiana field. Trenton limestone gas is without a doubt a very valuable fuel, and any effort to husband the supply should receive the hearty co-operation of every person interested in the natural gas industry.

ORIGIN AND ACCUMULATION OF NATURAL GAS.

Questions concerning the origin and accumulation of natural gas have been discussed for a number of years. Much has been said and many theories advanced to account for this hydrocarbon. I will not attempt to discuss these, or to propose anything new on the subject. Our most eminent geologists and chemists have observed, experimented and theorized on the subject, and I could add nothing new, even if I had the time and space at my command. I shall give briefly the views most commonly accepted by those who are seeking knowledge on the subject, and

* Vol. 6, of the Repts. of the Ohio Geol. Survey, 1888, p. 138.

leave the discussion of them to that vast army of scientists who are spending their lives seeking the truth concerning the innumerable phenomena that surround us.

Those who desire an elaborate discussion of the subject will find it in volume 10, of the Reports of the Tenth Census, 1884; volume 6, of the Reports of the Ohio Geological Survey, 1888; in the Eighth and Eleventh Annual Reports of the United States Geological Survey, 1889–90; and the Annual Report of the Geological Survey of Pennsylvania, 1886. These reports have been consulted freely in the preparation of this report, and acknowledgment is hereby made to the authors of the various articles contained therein.

The theories that have been advanced to account for the origin of petroleum and natural gas, as well as the other members of the bitumen series contained in the earth's crust can be divided into two classes, viz., inorganic and organic. The advocates of the former class regard these hydrocarbons as a result of the action of certain chemicals on mineral matter in the interior of the earth, while those of the latter class regard them as the result of the decomposition of organic matter contained in the rocks. Both of these were framed and have been advocated by eminent scientists. The inorganic theory has had but few friends among geologists. It was framed by chemists and chemists have been its chief advocates. The main objection to this theory is that it fails to take into consideration known conditions and characteristics of these products, as well as the geological facts involved, and for these and other reasons it has never received much consideration by the geologists of either continent.

The organic theory is accepted by nearly every one that is giving the subject thought at present. According to it, petroleum and natural gas are the result of the decomposition of organic matter, stored in the rocks in which they are found or associated strata. This is the general conclusion to which nearly all agree, but the limitations that have been thrown around it, and the provisions that have been attached to it by those who are seeking to account for the origin and accumulation of these products have been many. In one instance limestone is counted the principal source of natural gas, and in another it is referred to bituminous shales. By some it is claimed that it is indigenous to the rocks in which it is found, and by others it is counted adventitious; or in other words, the advocates of the indigenous origin of natural gas contend that the decomposition was effected in the rocks in which the gas is found, while the advocates of the adventitious origin claim that the gas was generated in the rocks in which the organic matter was deposited, and has been carried by hydrostatic pressure to an overlying stratum that serves as a reservoir. In fact the views of leading geologists are so different in many respects that each may be said to constitute a different theory, none of which is universally accepted, "and here, as elsewhere, it is no doubt true that theorists are somewhat oppo-ed to one another, because they respectfully regard but one side of a subject which has more than one side."*

As to the general view given above, it has much to commend it and little to condemn it. The arguments in favor of it are both logical and conclusive. That petroleum and natural gas are found and have their origin in the rocks of the earth's crust no one denies This being admitted, the material from which they are generated is located. The fact that large amounts of animal and vegetable matter were deposited with the material that forms the sedimentary rocks, and that this organic matter contains the elements of oil and gas is never questioned. Why should it be? Proof is abundant and accessible to all. Who has not been a witness to the decomposition of organic matter on the surface. Then it is that the dissolution is perfect and completed quickly; every atom of the body except the mineral matter being resolved into gas, escapes into the air. The organic matter of the earth's crust was deposited under different conditions. There it was soon buried under an accumulation of sediment which prevented both a perfect and a rapid decomposition. The fact that the disintegration was very slow in some of the formations is witnessed by the large number of fossils contained therein. But whether the decomposition was rapid, allowing the resulting products to escape in to the atmosphere; or whether (on account of the accumulated overlying deposits of sediment excluding the air, and the proper condition of temperature) this process of decomposition and the consequent evolution of gas has continued for centuries, and will continue as long as undecomposed organic matter remains in the rocks, the result is practically the same, except, in the one case the gas is lost in the atmosphere, and in the other, under certain conditions necessary to gas accumulation, it remains imprisoned in the rocks until it is set free by the drill.

In consideration of the results of the experience and observation of those who have had abundant opportunities for both, I think that it is reasonable to conclude that petroleum and natural gas have their origin through the decomposition of organic matter contained in the rocks. In regard to the various limitations that have been placed against the above conclusions, I think that I am safe in saying that a majority of them are true. I am aware that the fact that some of these views are opposed to each other, renders this statement seemingly inconsistent, but we must remember that this difference in the views of different theorists is largely due to the difference in location. In Indiana the Trenton limestone is the source of large deposits of natural gas, while in Pennsylvania the

*Orton. Eighth Annual Rept. U.S. Geol. Survey, 1889.

supplies are derived from the Devonian shales. Natural gas stored in the limestone is certainly indigenous, while that stored in sandstone is adventitious and can be referred to the underlying shales; and in like manner it is possible to dispose of many of the theories that have been advanced. They have a local application only.

An examination of the geologic and geographic distribution of natural gas will reveal the fact that while it is found in nearly every country and geologic formation, it has been in the Trenton limestone of Indiana, the Berea grit and Trenton limestone of Ohio, and the Devonian, Carboniferous and Catskill sandstones of Pennsylvania that the commercially valuable deposits have been found. It is evident from the above that however important *source* is to the accumulation of gas or oil, it is not the only condition necessary.

A careful examination of any one of the gas fields mentioned above, and a study of the conditions surrounding it will disclose the fact that there are a number of other conditions that are necessary to gas accumulation, and an examination of other fields will show the same facts. They are universal. These conditions named in the usual order are source, reservoir and cover, In the Indiana gas field the Trenton limestone is both the source and the reservoir. This formation is one of the most widespread formations on the continent. It underlies the entire State and approaches nearest the surface at Lawrenceburg, in the southeastern corner of the State, where it can be found at a depth of 349 feet.

While it is true that the Trenton limestone is a universal formation in this State, and is a reservoir for natural gas and oil, it is equally true that these products occupy but a limited strata of this limestone and a comparatively small area of the State. The cause of this is found in the textural and structural conditions of the gas-producing rock. Trenton limestone is seldom a gas rock below sixty feet from the upper surface, the gas producing stratum ranging from five to twenty feet thick. Observation and the analysis of this rock show that its productiveness is due to its porosity. Wherever the Trenton limestone is a gas or oil rock, it is always substantially a pure dolomite; highly crystalline and of a sufficient porosity to contain large quantities of these hydrocarbons. Its storage capacity is much greater than that of sandstones Outside of the gas area the conditions are different. There the limestone is nearly pure and non-porous. The dolomitic change has not taken place.

From the above it is plain that the porosity of the Trenton limestone is due to its chemical composition, or at least connected with it. In the oil and gas area this limestone has been transformed in its upper beds; the carbonate of lime giving way in part to carbonate of magnesia.

While it is true that oil and gas deposits are confined to a porous limestone, it is also true that this limestone is not always a productive gas or oil rock. There are other causes besides the lack of a porous rock to serve as a reservoir that may render limestones unproductive.

Of the necessary conditions for gas production, one of great importance is the reservoir cover: The accumulation of large deposits of gas would be impossible if the reservoir was not protected by a practically impervious cover. In Indiana the Utica shale serves this purpose. Though this formation does not come to the surface in this State, its composition and character are well known. It is impervious to water and gas, and forms a perfect cover for the Trenton limestone.

As has been incidentally mentioned, all the conditions necessary to gas yield have not been given. In order that petroleum and gas may accumulate in valuable quantities it is not only necessary that a rock, the formation of which is suited to the storage of these products, be present and that it be covered with an impervious roof, but it is equally necessary that the rock containing these hydrocarbons possess a structural relief sufficiently elevated to allow the various substances occupying the reservoir to arrange themselves in the order of their specific gravity, that is, the water, the oil (if any) and the gas on top. The required elevation of the relief is relative and not necessarily absolute. The productiveness of the reservoir seems to depend upon its elevation as related to the adjoining territory. The Cincinnati arch meets this requirement in the Indiana field. Its boundaries and structural peculiarities have been practically defined from the records of a number of wells drilled in the territory which it occupies.

In Indiana this arch is a low, broad elevation that crosses the eastern boundary of the State between Lawrenceburg and Liberty and extends in a northwestern direction across the State. Its surface is very uneven in places, consisting of numerous small ridges or folds, with occasional spurs extending at various angles from the main elevation.

A series of maps, prepared by E. P. Cubberly, President of Vincennes University, and designed to show "Indiana's structural features as revealed by the drill,"* illustrates the surface of the Trenton limestone very plainly.

The presence of this arch supplies one of the very necessary conditions for gas yield in this State, for the reason that it acts as a trap in which the gas accumulates. This arch or dome usually contains a number of substances arranged in the order of their specific gravity, the gas being held at the top under an enormous pressure, due to the weight of a column of water back of it. The Trenton limestone which comes to the surface in New York and Pennsylvania on the east, Iowa and Wisconsin on the west, Kentucky on the south and Michigan on the north, forms a

*"Eighteenth Ann. Rept. of the Dept. of Geol. and Nat. Resources of the State of Indiana," 1894.

large basin in which the Cincinnati Arch is located. The water entering at its outcrops flows towards its center and rises in the dome or arch, driving the gas and oil (if any) before it until the resistance of these products is equal to the weight of the column of water. The cause of the pressure of gas is plain. It is the same as that which causes the water to flow from artesian wells.

GAS PRESSURE AND MEASUREMENT.

Rock pressure in gas wells is the pressure exerted by the gas when confined within the well. A vigorous well, the flow of which is not retarded in any manner, will reach its maximum rock pressure almost instantly, while wells of feeble flow sometimes require hours. The open flow pressure of gas is the pressure that it shows when it is allowed to flow freely into the air. To obtain the rock pressure of a well, an ordinary high pressure steam gauge can be used, while to obtain the open pressure it is frequently necessary to use a water gauge, especially if the volume of flow is measured from the casing.

The amount of gas in cubic feet that a well discharges in a given time can be ascertained from the open flow pressure. The method in general use is one devised and given to the public by Prof. S. W. Robinson, of the Ohio State University. This method, which is an application of Pitot's tube, is easy to apply, and by it the strongest well can be measured. To avoid error it is necessary to exercise great care in the measurement of gas wells. A very simple and convenient apparatus is a small thin-walled tube, bent right angled or with an elbow. The open mouth of this tube, to obtain reliable results, should be filed square and reamed out inside to a nearly sharp edge. The joints and connection with the gauge should be air tight. The open mouth of the apparatus should be held in the current of gas at the well head, and the gauge should be held in the same position as when last tested. Usually the Pitot tube is held even with the top of the well tubing, and in the center of the orifice from which the gas is discharged. This will not give reliable results. Numerous experiments have proven beyond a doubt that the velocity of the gas varies at different points between the center and the sides of the orifice.

Dr. Phinney, of Muncie, Ind., in his monograph on "The Natural Gas Field of Indiana,"* reported a number of tests made by Mr. William Moore, of Kokomo, to ascertain the variation in the velocity of gas escaping from an open pipe at the different points between the center and sides of the pipe. For the benefit of those who have not access to this report, the results of these tests are given below:

* Eighth Ann. Rept. of the U. S. Geol. Survey, 1886.

PART OF ESCAPE PIPE.	Flow Pressure, Pounds.	Velocity per Second, Feet.	Capacity.
Center	10¾	1,293	5,482.944
One-fifth distance from center to side	10½	1,282	5,436,228
Two-fifths distance from center to side	9⅝	1,226	5,198,860
Three-fifths distance from center to side	8	1,139	4,829,943
Four-fifths distance from center to side	6⅓	1,049	4,444,076
Side of escape pipe	5¼	914	3,875,827

Reliable results are obtained only when the average velocity of flow is ascertained. In order to obtain this the tube should be held at about the first fourth of the diameter of the well tubing from the center, and if at the center the registered pressure should be multiplied by .97 Prof. Robinson's method of measuring the volume of flow of natural gas is fully explained in Volume 6, of the Reports of the State Geological Survey of Ohio, 1888; also in a small pamphlet published by him.

THE INDIANA NATURAL GAS FIELD.

The Indiana natural gas field is in the eastern central part of the State and occupies the following counties in whole or in part, viz.: Blackford, Decatur, Delaware, Grant, Hamilton, Hancock, Henry, Howard, Jay, Madison, Miami, Marion, Rush, Shelby, Tipton, Wabash and Wayne. Within the counties named above a number of small areas of barren territory have been found, territory in which the Trenton limestone is very hard and wanting in that condition of porosity that is necessary to gas yield. In some instances only a very small portion of the county is in the gas area, the remainder being barren, either for the want of the proper textural conditions or the necessary elevation of the porous stratum of the limestone. The map that accompanies this report gives the location of the main gas field; that is, the territory that has produced gas in commercially valuable quantities at any time during the history of this field. Owing to the encroachment of salt water, the gas producing territory is becoming smaller. This will continue until finally the salt water will possess the entire reservoir in which the gas is now stored. The main gas field contains an approximate area of 2,500 square miles.

Although wells have been drilled for gas in a number of counties outside of the gas belt, the results have not been satisfactory. In some instances a moderately strong flow of gas was found, but it was usually derived from other horizons than the Trenton limestone, and was soon exhausted. When it be ame known that within the Trenton limestone in Indiana large quantities of high-pressure gas were stored, companies were organized for the purpose of exploration in many towns and cities of the State, and as a result many deep wells have been drilled. From an economic point of view, much labor and capital were lost by these prospectors, but as a recompense in part for this loss the records of the

wells have furnished a large amount of information regarding the geological structure of the State. The data thus obtained has not only helped to solve the questions concerning the accumulation and distribution of gas, but it has added much information to the geological history of the State.

The surface of Indiana is a broad plain interrupted by the valleys of the water courses; its elevations varying from 378 feet in Vanderburgh county to 1,225 feet in Randolph county. A section of the rock formations of the gas fields as revealed by the drill shows that the great mass of rocks are limestones and shales. A description of the entire series is interesting and those who are seeking knowledge on the subject will find the records of all the deep wells that have been reported and a description of the rock formations of the State in the annual reports previously issued by the State Geologist.

Previous to the drilling of deep wells in Indiana for gas and oil but little was known of the thickness of the drift. The records from these wells have not only given us the vertical range of this formation in nearly every part of the State, but in addition we have obtained data that enables us to trace the history of this deposit. The thickness of the drift relates to natural gas only in so far as it serves to show the character of the surface of the adjacent rock formation. Small pockets of gas are occasionally found in it, but they seldom prove valuable, never indicating gas in the rock beneath, and are soon exhausted. The vast deposit of drift that covers the surface rocks of the entire State varies in thickness from nothing, or a few inches, to 500 feet. It is composed of clay, sand, gravel and boulders, with occasional remains of vegetable life, and in many places shows that it has been assorted by the action of water.

TRENTON LIMESTONE.

The Trenton limestone, on account of its being the reservoir for natural gas and oil in Indiana, is the most important formation in the geologic scale. It has a wide range, outcropping in the adjoining States, and throughout this gas field is near 500 feet thick. As has been noted in another section of this report, the upper stratum of this limestone is a dolomite; that is, a limestone in which a chemical change has taken place; in which the carbonate of lime has been partly replaced by carbonate of magnesia. The result of the change is a porous rock suited to the accumulation of large quantities of gas The relief of the Trenton limestone is its most important feature in this State. This, in the form of a low, broad arch, enters the State at the southeast corner at a depth of 349 feet, 158 feet above sea level, and with a gradual descent, continues in a northeastern direction across the State. The dip of the rock is more rapid to the northeast and southwest. The surface of the ridge, or arch, as it is called, is gently undulating, with occasional domes and transverse ridges. The following table will supplement what has been said regarding the thickness of the drift, and the surface of the Trenton limestone. A careful study of it will reveal the structural peculiarities of the Cincinnati arch.

Tables showing the thickness of the drift, the depth of the Trenton limestone and its altitude with reference to sea level. For much of the data in this table, acknowledgments are due Dr. A. J. Phinney, Prof. E. P. Cubberley, and the Principals and Superintendents of Schools who have rendered me aid in this work.

County.	Town.	Thickness of drift in feet.	Depth to Trenton limestone.	Altitude of Trenton.	
				Feet above sea level.	Feet below sea level.
Adams	Decatur	39	1,020		223
Allen	Fort Wayne	110	1,437		650
Bartholomew	Columbus	26	955		311
Blackford	Hartford City	82	935		40
Blackford	Montpelier	17	958		110
Boone	Lebanon	210	1,518		302
Cass	Galveston	40	920		180(?)
Clinton	Frankfort	278	1,060		227
Dearborn	Lawrenceburg	139	349	158	
Decatur	Greensburg	10	920	22	
Dekalb	Auburn	282	1,941		1,069
Delaware	Muncie		878	67	
Delaware	Eaton		890	5	
Elkhart	Goshen	165	1,815		1,026
Fayette	Connersville	97	705	117	
Franklin	Brookville	157	550	174	
Fulton	Rochester	248	1,161		531
Grant	Fairmount	38	934		41
Grant	Marion	70	877		67
Hamilton	Arcadia	130	960		93
Hamilton	Noblesville	140	844		76
Hancock	Greenfield	215	985		54
Henry	New Castle	500	876	117	
Henry	Spiceland	150	948	85	
Howard	Kokomo	61	948		87
Huntington	Huntington	2	995		255
Jackson	Seymour	72	1,100		472
Jasper	Rensselaer	30	910		158
Jay	Portland	58	990		63
Jay	Red Key	72	980		90
Jay	Dunkirk	60	930	39	
Jennings	North Vernon	11	980		253
Madison	Alexandria	20	897		40
Madison	Anderson	114	814	66	
Madison	Elwood	108	924		66
Marion	Indianapolis	118	900		179
Miami	Amboy	35	907		100(?)
Montgomery	Crawfordsville	140	1,439		664
Morgan	Martinsville	85	1,397		780
Newton	Kentland	100	1,060		379
Park	Rockville	96	2,100		1,412
Porter	Valparaiso	125	1,300		602
Pulaski	Francesville	8	885		200
Randolph	Farmland	55	985	45	
Randolph	Ridgeville	30	981	1	
Randolph	Winchester	147	1,050		42
St. Joseph	South Bend	160	1,600		855
Shelby	Shelbyville	48	837		79
Tipton	Tipton	139	997		129
Wabash	LaFontaine	300	900		6
Wayne	Richmond	5	895	79	
Wayne	Cambridge City	96	767	174	
Wells	Bluffton	51	1,075		338
White	Monticello	205	1,010		338
Whitley	Columbia City	224	1,369		525

This high-lying area of the Trenton limestone in Indiana furnishes the reservoir for the supply of natural gas. The highest portion of the arch or incline is not a reservoir, for the reason that it does not possess the proper textural condition. It may be said that natural gas in Indiana is stored in the slope of an incline, and that the textural condition of the rock above the reservoir prevents it from escaping at the outcrop.

Around the productive gas area is found the salt water that has accumulated in the porous rock. Being caught at the outcrop of the formation, it has flowed down the incline and occupies the lower portion of the porous rock, the gas, oil and salt water occupying a common reservoir. The salt water is the force back of the gas, and when this hydrocarbon is exhausted it will fill the reservoir. Around this gas field is a line below which salt water is always found. As the supply of gas diminishes, the salt water horizon advances toward the highest point in the reservoir. There is a constant warfare between the salt water and the gas for the possession of the reservoir. The height to which the salt water rises in different fields depends upon the elevation of the source of the water and the reservoir. In this field it is found at a depth of less than 100 feet below sea level, and the upper limit of productive rock will not exceed 90 feet above sea level. It is probable that the total range of productive rock will not exceed 160 feet.

Salt water is the most dangerous and difficult element with which gas companies and owners of gas wells have to contend. They realize this, and are doing all in their power to thwart its progress. While it is true that as the supply of gas diminishes the water rises higher in the reservoir, hermetically sealing all wells in which the pressure of the gas is not strong enough to hold the water back or raise it to the surface, and that the ultimate result is known and certain, it is also true that much can be done to check its progress, thereby extending the life of the present supply. Great care should be exercised in drilling new wells, in order that the productive rock may be penetrated without molesting the salt water. Wells showing signs of water can be made to yield gas for a considerable time with proper care. Like any other class of property, gas wells need constant attention.

There is scarcely a resident of this State that is not familiar with the early history of the Indiana gas field. The fact that Trenton limestone, a universal formation in this State, contained a vast store of this gaseous fuel, awakened an interest that had not been known. Wherever a sufficient amount of money could be raised to put down a well, the drill was started on its journey. Before the gas field was located with any degree of accuracy, vast sums of money were expended by individuals and gas companies. Some were rewarded, but many were doomed to disappointment. Soon the gas field was located, and the success of the drill was seldom questioned.

The Indiana field soon attracted the attention of manufacturers who knew the advantages that natural gas possessed over other fuels. In a short time the manufacturing interests of the gas belt had increased wonderfully, millions of dollars being invested in this industry The villages and towns have experienced a phenomenal growth, and the wealth of that portion of the State has increased many fold.

In 1880 there were seven States that manufactured more glass than did Indiana; in 1890 there were but three. The value of the glass product in 1880 was $790,781; in 1890 it was $2,995,409, being nearly a four-fold increase. In 1880 there were four glass manufactories, valued at $1,442,000 and employing 862 persons. In 1890 the number of factories had increased to 21; the capital invested to $3,556,563, and the number of employes to 3,089. The growth of the iron and steel industry has been equally rapid. In 1880 there were nine establishments, valued at $1,820,000, and employing 1,740 persons, who received $810,000 annually in wages. In 1890 there were 13 establishments valued at $3,888,254 and employing 2,644 persons, who received annually $1,215,702 in wages.

From the above it will be seen that the growth of the manufacturing industries of the Indiana gas field during its early history was phenomenal, but a comparison of its condition in 1890 with 1895 will show a growth even more rapid. There were near 50 glass factories in operation January 1, 1895, the value of which was not far from $5,000,000. It requires 7,000 employes to operate these factories, and the annual pay-roll amounts to $3,000,000.

The statistics given above show, in a measure, the growth of the glass and iron industries since the discovery of natural gas. While this gaseous fuel is peculiarly adapted to certain lines of manufacturing, it possesses advantages over wood and coal that are recognized by the manufacturers of all classes of products, and the result is that nearly every class of manufacturing is represented in the Indiana gas field.

The history of one gas field is practically the history of all. Of course each field has its own peculiar limitations. The supply of one field may outlast that of another, but at best they last but a comparatively short time. There was a time in the history of the Indiana field when the only proof of the above was theoretical. Now we have had the practical demonstration. In 1884 natural gas was discovered in the Trenton limestone in Ohio. The supply seemed inexhaustible, and with that idea in mind it was exhausted. The history of that field is practically finished, and the life of the Indiana field will be shorter on that account, for the pipe lines now constructed transport a large amount of gas to Ohio, and will probably continue to do so until this field is exhausted.

That millions of cubic feet of gas have been wasted, either by allowing it to escape into the air or by burning it to show its abundance, no one will deny. The causes that have led to this wanton waste that has continued for years are numerous. It is not worth the while to enumerate or discuss them here. We are more interested in the effect than the cause.

CONDITION OF THE FIELD.

Manufacturers, gas companies and private consumers are alike interested in the present condition of the gas field. It takes no argument to convince them that gas is failing, and in view of the advantages that are being derived from the use of this fuel, the decline of the rock pressure, the encroachment of the salt water and the increased consumption from year to year are, on account of their relation to the future supply, questions of great importance. The original rock pressure was 325 pounds to the square inch. This pressure was practically uniform throughout the field. Some wells showed the maximum pressure instantly, while others required hours. When a well is closed it forms a part of the gas reservoir, and its pressure will reach the maximum pressure of the immediate neighborhood if allowed to remain closed long enough. The large draught that has been made upon the Indiana field since its discovery has materially reduced the rock pressure. It is admitted by all, I believe, that any material reduction in the rock pressure of a gas field indicates a diminution in the supply.

A comparative statement, giving the rock pressure of a number of wells located in different parts of the field, and taken at intervals of six months or a year, would show the rate of decrease and would be interesting to all who are interested in the natural gas industry. Unfortunately the data is not at hand from which a statement covering the entire field can be made. A record of the pressure of a number of wells located in different sections of the gas field is given below. They were tested during the summer of 1895, and, unless otherwise stated, are located in or near the city named.

The record given was obtained principally from new wells and is the maximum pressure of that section of the field.

ROCK PRESSURE OF THE INDIANA NATURAL GAS FIELD, 1895.

	Pounds Pressure.
Blackford County—	
Hartford City	270
Delaware County—	
Muncie, one mile north of town	200
Muncie, three miles north of town	250
Royerton	250
Daleville, one mile west of town	225

	Pounds Pressure.
Grant County—	
Marion, three miles southwest of town	255
Marion, three miles southeast of town	260
Jonesboro	270
Gas City	270
Swayzee	250
Hamilton County—	
Noblesville, two miles north of town	200
Arcadia, six miles east of town	230
Olio	200
Hancock County—	
Greenfield, three miles north of town	210
Henry County—	
Middletown, three miles north of town	220
Howard County—	
Fairfield	240
Greentown	255
Guy	255
Jackson Township	250
Jay County—	
Camden	150
Dunkirk	225
Red Key, four miles soutwest of town	250
Madison County—	
Alexandria	255
Anderson, four miles east of town	230
Elwood	255
Frankton, four miles south of town	245
Chesterfield, three miles north of town	235
Orestes	255
Lapel	220
Perkinsville	230
Pendleton	225
Rush County—	
Carthage	150
Tipton County—	
Prairie Township	205
Wild Cat Township	250
Hobbs	250

The difference in the pressure of wells in different sections of the field is mainly due to the difference in the texture of the Trenton limestone and to consumption. If all the wells in the field were closed, there is little doubt but that the pressure would be uniform throughout the entire field. The initial rock pressure of the Indiana gas territory was 325 pounds. The average rock pressure of the gas producing portion of the original gas area at present is about 230 pounds; a decrease of 95 pounds. There is little doubt but that the pressure of the field will decrease more rapidly in the future than it has in the past.

The supply of gas is diminished by waste and consumption, and while the amount wasted is growing less, the annual consumption is increasing. New pipe-lines are being constructed. The field pressure is being re-enforced with pumps and extra inducements are offered to consumers. Factories continue to locate in the gas territory. Some of the largest factories in the gas belt have been built this year. Because of the increased manufacturing interests, the population of many of the towns is increasing rapidly. This all means an increased consumption of gas.

Much has been said of the amount of gas wasted as well as the manner of its use. This is well, for it is a subject that needs attention. That much gas has been wasted in the past, and that it is being wasted in some parts of the field at present, no one will deny. The questions are: how is it wasted and what is the remedy?

But few of the gas plants constructed in the early history of the gas field were planned or "put in" by practical gas engineers. This is especially true of the plants in the small towns and the country. More than this, many of the plants were constructed hurriedly and during the winter season, and in some cases inferior piping and fittings were used. The result of all this is, that many plants are very imperfect in both plan and construction. Wells in which the packers were not properly adjusted; piping too small for the work to be done; worn out regulators that were too small when in repair to properly regulate the pressure of the necessary amount of gas, are frequently found. While conditions such as are stated above have existed and do exist to some extent at present, I am glad to say that a large number of plants have been so thoroughly repaired during the past year that they are practically new; being much better than when first constructed, from the fact that the reconstruction has been made with reference to the work to be done. Larger regulators and piping have been used; the necessary high-lines and reducing stations have been added, and if satisfactory service is not given this winter, the fault will not be with the gas plant. With but few exceptions, the gas companies of the State are better prepared to give satisfactory service this winter than at any time during the history of the field. I do not mean by this that the supply of gas is more abundant, but the facilities to transport and distribute it are much better than they were one year ago. True, there are a few gas companies in the outer zone of the gas field that will not be able to give good service this winter. These towns are fortunate if they are near a pipe-line.

The small pipe lines referred to above, and in a few instances larger pipe lines, have, on account of imperfect fittings and the lack of care, been the source of much waste. It requires perfect joints, gates, valves, etc., to confine gas at well pressure, and the most perfect joint will, from the effect of the contraction and expansion of the pipes, caused by the variations in temperature, become defective, and a very small leak will cause much waste if allowed to continue. The remedy for this source of waste is plain. Some of the larger pipe-line companies keep men whose sole duty it is to detect and repair leaks in the small tributary lines that thread the gas territory in every direction. These lines should be gone over and repaired at least once a month. The only safe plan is to keep a watch over every avenue of waste. The very few large pipe lines that have caused trouble in the past have been so thoroughly repaired during the past summer that it is not probable that they will cause any more trouble.

Another cause of waste is the crude mixers and burners used by both manufacturers and private consumers. I am satisfied that, with scientific burners and mixers adjusted to the gas pressure, an equal amount of heat could be produced with one-half the amount of gas used in many cases. The full power of natural gas is not realized unless it is mixed with air. As to the proper proportion of air to gas there is a difference of opinion; ten of air to one of gas is not far from correct. If this proportion is to be maintained the pressure of the gas should not vary, for a mixer that will admit gas and air in the correct proportion when the gas is under a twelve-ounce pressure will admit a larger amount of gas if the pressure is increased to sixteen ounces. Ninety-six cubic feet of gas under a pressure of three-tenths of a pound will pass through a No. 7 mixer in one hour, while under one pound pressure one hundred and seventy-nine cubic feet will pass through the same mixer in the same time. It is evident from the above that when a mixer is so adjusted that the gas and air are admitted in the proper proportion, the pressure of the gas should not be changed, unless the amount of air admitted is changed to correspond. To see that the burners and mixers are clean and properly adjusted is the duty of the consumer, and in like manner it rests with the gas company to furnish the gas at a uniform pressure. This can not be done without the necessary high lines, reducing stations and regulators.

Should natural gas be sold by meter measurement or by contract, and what relation does this subject bear to the manner in which gas is used, are questions that have been discussed in the annual reports from this department, in the newspapers and by the consumer. Inasmuch as the subject has received more attention in the past than in all probability it will in the future, it will not be given much space here. Theoretically, there can be no question as to the right in this matter. If natural gas is property, and can be transferred as other property is, it will harm no one to pay for it as he pays for other property. Those who are opposed to the "meter system" contend that the adoption of it means a higher price for gas. While that may be true, it is not necessarily so. I can see no reason why the prices under one system could not be adjusted as fairly and as satisfactorily as under another. A schedule of prices under which I am compelled to pay for the gas which I use, and no more, is certainly just. If I choose to practice economy, a reduction in the cost of my fuel is the reward; if I use it extravagantly, I pay for what I use and no more.

While the incentives to practice economy in the use of gas are not quite as great under the present system as under the "meter system," the prosperity and general welfare of the gas belt and State should prompt every one to do all in his power to husband the present supply of this gaseous fuel.

NATURAL GAS AS AN ILLUMINANT.

While the chief value of natural gas does not lie in its illuminating power, it has been used for this purpose from the time it was discovered. The flambeau, at first a luxury, by long use has seemingly become a necessity. The time has been when apparently the entire gas field was illuminated with gas torches. In many places they were allowed to burn day and night, year in and year out. A vast amount of gas has been wasted in this way. There are reasons why farmers and villages should use this gaseous fuel as an illuminant in the same manner that any other light is used; that is, burn it when needed and extinguish when not; but why large torches should be allowed to burn day and night in villages and the country, and in the glare of the electric light in cities, I am not able to say.

The General Assembly of 1891 enacted a law prohibiting the use of natural gas in flambeaux, and prescribing how it can be used as an illuminant This law has encountered much opposition. Those who are opposed to it contend that it abridges their rights as citizens; that natural gas is property and as such the owner has a right to use it as he desires. In opposition to this it is claimed that the enforcement of the law is a judicious exercise of the police powers of the State; that the welfare and prosperity of the public overshadows the good of the individual.

When I took charge of this Department natural gas was used in flambeaux in a majority of the towns and villages of the gas field. In many sections of the field torches could be seen burning in farm yards and gardens day and night. The past year has witnessed a change in public sentiment on the question. The law is looked upon with more favor. Realizing that the use of gas in this manner is extravagant and detrimental to the prosperity of the gas territory, as well as in defiance of the law, a number of villages and towns have either taken down their flambeaux, or ceased to light them. In many instances a single request was sufficient. Farmers have been slower to act. Many own their own wells, and those that do not usually claim the privilege to use gas as they please under the terms of their gas lease.

Recently two suits were brought in Blackford County to enforce the law. In the Circuit Court the defendants entered a motion to quash the affidavit, and by their motion attacked the constitutionality of the law. The Court overruled the motion to quash. The question will soon reach the Supreme Court, and upon its decision will rest the question, as to whether flambeaux will be allowed to burn or not. The object of the law is not to prohibit, but to regulate the use of natural gas as an illuminant. Because its use is prohibited in flambeaux is no reason why villages and towns should be left in darkness, or farm yards without light. The experience of a number of small towns shows that the use of natural gas in "jumbo" burners, or burners of similar character, enclosed in glass lamps, is practical. The light is not the best, but is better than many cities enjoyed prior to the introduction of electricity as a lighting power. Natural gas used in this manner is not wasteful or extravagant.

It is because natural gas possesses superior advantages as a fuel that its waste should be discouraged. When the supply is exhausted some other fuel will be substituted for it, but it is not probable that it will equal it in all respects. We know what it is to enjoy the luxury of its power. Let there be a united effort to use it for those purposes for which it is most valuable, and in the most economical manner possible.

THE FUTURE OF THE INDIANA NATURAL GAS FIELD.

What will be the future history of the Indiana natural gas field? How long will natural gas last? When referring to the natural gas industry, these are the questions most often asked. There was a time in the history of this field when questions like the above did not receive much attention. The seeming abundance of the supply, the power that it exerted as it escaped from its rocky prison, the large area of gas territory, and, in fact, the nature of the product, all seemed to preclude the idea of its exhaustion in the near future. The supply has been equal to the demand since the discovery in 1886, a period of nine years. How long it will continue to honor the enormous draughts that are being made upon it, from year to year, I can not say. The fact that we have entered upon the period of decline, that the supply is failing and will finally be exhausted, is not questioned. Not only is the evidence of such present in the field, but the history of other fields, that were limited by conditions similar to the ones with which this field has to contend, foretells to some degree the future of the Indiana field.

The main fact, settled by the history of the Pennsylvania and Ohio natural gas fields, is that a reservoir of natural gas can be exhausted. However, on account of the difference in the size of the reservoirs and the amount of gas consumed, no two fields can be compared as to duration. Developments began in the Findlay field in 1884; ten years later it was practically exhausted. The salt water and oil had overrun all portions of the gas rock. We can not compare the Indiana field with the Findlay field, for though alike in a few respects, they differ materially in many. The Findlay and Wood County fields of Ohio, do not include to exceed 100 square miles. The Indiana field does not contain less than twenty times this amount. This does not necessarily indicate that the life of this field will exceed that of the Ohio field, for an increased area affords the opportunity for an increased consumption. While this is true, I have reason to believe that the ratio of the consumption of the Indiana field to that of the Findlay field is not as great as is the ratio of the area of the former to the latter.

Successful explorations began in Indiana in 1886, and after nine years of active operation there remains thousands of acres of good gas territory that is not developed, except an occasional well to supply farmers. A large part of this is owned by pipe-line companies who are holding it in reserve. A number of towns in the interior of the field are drawing their supply from wells drilled within the corporate limits of the town during the early history of the field. In a few instances, this long period of service has not materially reduced the production of the well. The above has especial reference to the smaller towns. As a general rule the larger towns that have succeeded in locating a number of manufactories are widening the horizon of their operations from year to year, piping their gas from three to ten miles.

Another condition that is related to the capacity of the reservoir and consequently has an influence on the duration of the gas field is the vertical range of the gas producing rock. In this, the Findlay field seems to have an advantage over the Indiana field. As to the manner of using gas, the methods, purposes and devices are substantially the same in every field. Natural gas has never been used as economically in any field as its value would suggest. The probable reason for this is that its cost seldom equals its value as a fuel. This is especially true of manufactories, a large majority of which are either using "free gas," as a part of the remuneration for the location of their factory, or are supplied from wells that they have drilled in territory received in the same way. In either case the cost of the fuel is a very small per cent. of its value.

Those manufacturers who measure the gas that they consume, and pay for it accordingly, do not allow fires to burn that are not needed. They use natural gas as they would any other heating or lighting power. Without regard to whether natural gas is bought by meter measurement, by contract or is received as a gratuity, there is no reason why it should not be used with due regard to its value as a heating power. Let us keep in mind that we are drawing on a definite stock of this product; that a certain amount can be used for a number of years, and when the supply is once exhausted there is no provision for its renewal. It is in the light of the above that the extravagant use and waste of this gaseous fuel should be viewed.

What effect the oil field will have on the natural gas area is difficult to foretell. It depends somewhat upon the future explorations. The present field extends eastward from Marion, around the edge of the gas area to Portland. It includes portions of Grant, Huntington, Wells, Blackford, Adams and Jay counties. Active operations are extending in every direction, and the indications are that this will continue to be a productive field. Any extension of the oil area to the southward will come within the limits of very productive gas territory, and there is no doubt but that the development of oil territory is injurious to the natural gas interests. Indications of oil are sufficient in a number of localities in the interior of the gas field to start prospectors for this product. If this continues, the natural gas industry will soon feel the effect of it.

The gradual decrease of the rock pressure, and the encroachment of the salt water are the most important factors to be taken into consideration when discussing the future of the gas area. If the annual decrease in the rock pressure was unvarying, and the pressure at which the salt water overruns the gas rock was the same throughout the field, predictions concerning the future of the gas field would be of more value.

The initial rock pressure of this field was 325 pounds to the square inch. The average rock pressure of the gas producing portion of the original gas area is about 230 pounds at present. This is a decrease of 95 pounds in nine years or an average decrease of 10½ pounds per year. This decrease, however, has not been uniform. The first three years' consumption effected the rock pressure very slightly, especially in the interior of the field. Since that time, however, the annual decrease has been very noticeable and has increased with the years. I am not prepared to say what the decrease has been during the past year, but with the data at hand, will be able to give the effect of this winter's consumption.

The history of all gas wells in the Indiana field is, that they continue to produce gas until the weight of the salt water overcomes the pressure of the gas. When does this occur, or what pressure is necessary to hold the salt water back, are questions that can not be answered definitely. In some parts of the field the danger point is reached at 200 pounds, while in a few instances, wells in which the pressure has been reduced to 50 pounds are producing gas in commercially valuable quantities. The causes of these conditions are uncertain. The increased consumption of gas is undoubtedly a cause of the increase of the diminution of the rock pressure of the field. Other causes are probably present. As to the pressure at which the salt water overruns the gas rock, it is possibly effected by the textural and structural conditions of the rock, as well as its elevation. The presence of these conditions precludes anything like an accurate prediction concerning the life of natural gas in this field.

As I have said a comparison between the two fields is not practical. While they are alike in a few particulars, they are so unlike in many respects that the future of the Indiana field does not become much lighter under the rays of the history of the Findlay field. This field is peculiar in many respects, and the outcome and duration of it will depend to a large extent upon the manner in which its product is used.

I have frequently referred to the waste of gas, and the effort that should be made to husband the present supply. The reasons for so doing are obvious. It is the question above all others that should be kept before the public mind. It has much to do with the future of the gas field. A strict enforcement of the law, re-enforced by a strong public sentiment in favor of an economy commensurate with the value of the product, will materially extend its life.

KOKOMO, IND., January 13, 1896.

Prof. J. C. Leach, Kokomo, Indiana:

DEAR SIR—I herewith respectfully submit to you a report on the utilization of natural gas, which I trust may meet with your approval. I have sought to make the article as practical and useful as possible and at the same time intelligible to the thoughtful reader. I have purposely avoided an unnecessary use of scientific terms and have endeavored to make clear the meaning of those I was obliged to employ. I have also avoided any theorizing on the nature and composition of the compounds which compose the combustible portion of the gas; though I must admit this has afforded me some interesting study. I realize that much more could be said, but space and time did not permit it.

Yours respectfully,

ELWOOD HAYNES.

UTILIZATION OF NATURAL GAS.

BY ELWOOD HAYNES.

Fuel is one of the necessary and fundamental elements of modern civilization. It not only contributes to the comfort of man, but it has enabled him the leave the genial climate near the equator and force his way into more rigorous latitudes farther northward, and rendered existence there not only possible but pleasant. It is the key that unlocks the great resources of nature and enables man to fashion them to his own use.

The three most important forms of fuel are wood, coal and gas. The former was probably first utilized by man for this purpose on account of the ease with which it could be procured and its low kindling temperature. It is also highly probable that charcoal made from wood, formed the "entering wedge" which opened up the vast treasures of the iron mine.

It is to mineral coal, however, that we are indebted for by far the greater portion of man's progress in the industrial arts of the present century. The use of gaseous fuel on an extensive scale is of very recent origin. It is true the Chinese have used natural gas in a very crude way in connection with salt production, but this was so limited that it is of little interest, except from an historical standpoint.

Another form of fuel, which is now utilized to a considerable extent, is crude oil, which has the advantage of being easily transported either by pipe line or by freight. We then have fuel in the solid, liquid or gaseous form. If we examine these fuels from an analytical standpoint we find that they are all composed of carbon and hydrogen united in different proportions. Every one who has witnessed the combustion of coal, wood, oil or gas has noticed at times a black deposit of soot on objects in contact with the flame. This black deposit consists of nearly pure carbon, which is one of the main constituents of all the fuels mentioned above.

The other constituent—hydrogen—when in the pure state is a very light, colorless, odorless and invisible gas It may, however, combine with carbon to form a solid, a liquid or a gas, as we have seen.

There is another element in nature which is necessary to combustion, which exists in the free state in the atmosphere. This is oxygen, and it must be present in sufficient quantity if perfect combustion is to be secured.

When combustion is taking place, or as we usually term it, "the fire is burning," the oxygen from the atmosphere is quietly uniting with the carbon and hydrogen of the fuel. When it unites with the carbon it forms an invisible gas called carbonic acid, which is the same gas that forms the bubbles that rise from a glass of soda-water when it is just drawn from the fountain.

The hydrogen of the fuel unites with the oxygen of the air to form water, which, of course, passes up the flue in the form of steam. In very cold weather the steam can be seen issuing from the chimney tops.

There is besides oxygen in the atmosphere another gas termed nitrogen which constitutes about four-fifths of its volume. This gas takes no part in combustion, but merely passes through the fire unchanged. It is evident, however, that a much larger volume of air is required to burn a given quantity of gas than would be necessary if the atmosphere consisted entirely of oxygen. It has been found that a given weight of hydrogen requires 8 times its weight of oxygen to burn it. A given weight of carbon requires $2\frac{2}{3}$ times its weight of oxygen in order to burn it to carbonic acid gas. We thus see that a given weight of fuel requires a weight of oxygen equal to 8 times the weight of hydrogen it contains plus $2\frac{2}{3}$ times the weight of the carbon it contains.

Or since the atmosphere is only about 23 per cent. by weight oxygen, we find that it would require about forty-four times as much air. Let H equal the weight of hydrogen, and C equal the weight of carbon in any given fuel, and W the weight of the air required for its combustion. Then

$$W = \frac{4.4\ (8C+8H).}{3}$$

In order to obtain the value of W it is only necessary to analyze the fuel and the weight of the air necessary to burn a given weight of it can then be computed from the above equation.

The first step in the analysis of a gas should be to obtain its specific gravity or the weight of a given volume, as compared with that of an equal volume of air.

This is best accomplished by weighing a given volume of each in a thin glass globe, and comparing the weights thus obtained. The weight of a given volume of air has been accurately determined, and thus the weight of a given volume of gas can be closely ascertained. It is evident that the sum of the weights of the constituents of the gas as shown by the analyses should equal the weight of the gas, which was taken for experiment. The composition of natural gas by weight has been found by analysis to be substantially as follows:

Carbon	70.25
Hydrogen	21.45
Sulphuretted hydrogen	.17
Carbonic acid	.02
Nitrogen (by difference)	7.93
Total	100.00

It would be interesting from a scientific standpoint to determine, if possible, the nature and composition of the mixed hydro-carbons which compose the combustible portion of the gas, but practically it is only necessary to know the weight of the carbon and hydrogen, in order to gain an accurate knowledge of its heating power.

It may be added, however, that as much as 85 per cent. of natural gas consists of marsh gas, which is composed of seventy-five parts by weight carbon and twenty five parts of hydrogen.

It is evident, however, that the hydrocarbons can not consist entirely of marsh gas, as the carbon and hydrogen are not in the proper proportions, as shown by the following analyses.

COMPOSITION OF THE HYDROCARBONS IN NATURAL GAS.

Analysis Made in 1894.		*Analysis Made in 1896.*	
Carbon	76.4	Carbon	76.8
Hydrogen	23.6	Hydrogen	23.2

The analyses indicate that the gas is nearly or quite constant in its composition. Substituting the values given in the complete analysis in the formula, we find that $W=4.4\ (\frac{562}{3}+171.6)=1,579.3$ lbs., the weight of air necessary to burn 100 pounds of natural gas.

Since the specific gravity of natural gas is .634, the volume of air required to burn 100 cubic feet of the gas is 1,001.27, or almost exactly ten times the volume of the gas consumed. In practice, however, it is advisable to use a little more air than is called for by the formula, in order to insure perfect combustion. If, however, the mixture can be made perfect it is not advisable to admit too much air, as all surplus air tends to carry away heat which might otherwise be utilized. A good method of regulating the "quality" of a gas flame is to adjust the air supply at the mixer in such a manner that there is just a slight white tip occasionally visible at the end of the flame, and then turn on enough air to cause this to disappear. It is not the purpose of this article to treat of the utilization of heat, but it will perhaps be in order to say something of the subject as it is of such great importance.

The appliances in most common use in the utilization of natural gas are: 1. Stoves. 2. Furnaces. 3. Grates. 4. Boilers.

The burner in a stove used for heating should be set as near the bottom of the stove as possible, and the flame of the gas should issue horizontally so that the tip should just reach the iron of the stove. This arrangement carries the hot gases upward in close contact with the interior wall of the stove, and thus enables the heat to penetrate the iron and pass into the room. There should also be a damper in the stove pipe to prevent too rapid escape of the hot gases from the stove.

The furnace is perhaps the most economical appliance for the utilization of heat for warming rooms. It is, moreover, when properly constructed, healthful and pleasant. But if not properly constructed, or if proper attention be not given to it, it may become the source of great annoyance and even danger to health. Placed as it usually is, in the basement, it renders certain the introduction of all the burnt gas, resulting from leakage, into the rooms above.

The carbonic acid and steam thus finding their way into the rooms are comparatively harmless; but there is another gas called carbonous oxide which is often produced from "smothered" combustion that is extremely poisonous. It is not advisable to sit or stand near a furnace register if there is the slightest odor of "burnt gas" perceptible, as the carbonous oxide here forms the highest per cent. of the air in the room. The remedy for the above is to have the furnace thoroughly inspected by a competent person who will see:

1. That the chimney draft is clear.
2. That the burner is clean.
3. That the air and gas are admitted in the proper proportions through the mixer.
4. That the pipes admitting air to the registers are tight.

Carbonous oxide is odorless and invisible, but its presence is manifested by causing a dizzy sensation often accompanied by headache.

The heat supplied to a room is of two kinds:

1. That supplied by direct radiation or radiant heat.
2. Heat by convection or that supplied directly from the stove to the air of the room. When we approach a very hot stove or an open fire we feel the effect of the direct radiation. This form of heat can pass readily through a vacuum, and does not depend upon air for conveying it from one object to another.

The stove heats both by direct radiation and by convection.

The furnace heats by convection only; as the air acts as a carrier for all the heat it supplies to the rooms. The grate or open fire, if built into the chimney, supplies heat by direct radiation only. It is a pleasant fire, but a very wasteful one. In very cold weather it is almost impossible to warm a room of any considerable size by a grate.

There are two reasons for this:

1. The heat being radiant can only warm the room by directly radiating against the floor, walls and furniture, and as its intensity diminishes with the square of the distance the amount of heat supplied to the room is limited to a small area very near the fire.
2. The draft created in the flue is strong in cold weather and the cold air rushes into the room at every crack and crevice, thus robbing the room of a great deal of heat. The best that can be said for the grate is that it is a cheerful fire and insures good ventilation if properly constructed. The remark that Benjamin Franklin satirically made of the old-fashioned fire-place can be applied with equal force to the modern grate: "It is the thing to use if one wishes to obtain the least amount of heat from the greatest amount of fuel." There is some hope, just now, however, that a stove will come into use which will have all the cheerfulness of the grate and an economy equal to the best stove. Whether a stove, furnace or grate is used it should have sufficient radiating surface to allow the heat to pass so rapidly into the room that the temperature of the gases in the stove pipe shall be reduced as far as possible before they pass out into the air. Notwithstanding the fact that considerable quantities of steam are carried out through the chimney it is not necessary that the temperature of these gases should be above the boiling

LIST OF NATURAL GAS COMPANIES—Continued.

Company.	Pres. or Secy.	P. O. Address.
CLINTON COUNTY.		
Terhune & Kirkland Natural Gas Co	G. M. Kutz	Kirkland.
DECATUR COUNTY.		
Benj. Jenkins Gas Co	Benjamin Jenkins	St. Paul.
Bracken & Hamilton Gas Co	Dr. Wm. Bracken	Greensburg.
Citizens' Gas Co	George Ewing	Greensburg.
Consumers' Natural Gas Co	George M. Kline	St. Paul.
Fourth Ward Natural Gas Co	Putt Ewing	Greensburg.
Greensburg Natural Gas, Oil and Water Co	Charles Porter	Greensburg.
Hamilton Natural Gas Co	Brutus Hamilton	Greensburg.
Hollensby Natural Gas Co	Jud Hollensby	Greensburg.
Muddy Fork Natural Gas Co	Hubert Eich	Greensburg.
Slippery Natural Gas Well Co	Oliver Hunter	Greensburg.
Stevenson & Emmerer Gas Co	Thom. Stevenson	Greensburg.
St. Paul Gas, Oil and Water Co	E. L. Floyd	St. Paul.
Thomas Healton Natural Gas Co	Thomas Healton	St. Paul.
Newton Natural Gas Co	Dollie Tilson	Greensburg.
DELAWARE COUNTY.		
Buck Creek Natural Gas Co	A. W. Ross	Muncie.
Cammack Natural Gas and Mining Co	W. F. McKinley	Cammack.
Central Cöoperative Fuel, Gas and Light Co	J. W. Ream	Muncie.
Citizens' Cöoperative Natural Gas Co	C. S. Watchtell	Muncie.
Compromise Natural Gas Co	L. O. Swingley	New Burlington.
Cleveland Gas Co.		DeSoto.
Cöoperative Gas Light and Fuel Co	L. H. Greer	Yorktown.
Cöoperative Fuel and Gas Light Co	J. F. Broyles	Gaston.
Cöoperative Natural Gas Co	J. M. Hancock	Daleville.
Cowan Exploring and Gas Co	W. H. Neff	Cowan.
Cross Roads Natural Gas Co	W. L. Swanger	Cross Roads.
Delaware Natural Gas and Mining Co	D. A. Black	Albany.
DeSoto Natural Gas and Mining Co	Eli Ogle	DeSoto.
Eaton Mining and Gas Co	C. K. VanBuskirk	Eaton.
Economy Natural Gas Co	F. J. Claypool	Muncie.
Farmers' Non-transferable Gas Co	A. D. Gray	Muncie.
Farmers' Natural Gas and Petroleum Oil Co	M. C. Ratcliff	Yorktown.
Farmers' Natural Gas and Oil Co	D. A. Funkhouser	Cross Roads.
Farmers' Natural Gas and Oil Co	Newton Weaver	Albany.
Forest Park Gas Co	W. H. Reed	Muncie.
Granville Citizens' Natural Gas Co	L. W. Davis	Granville.
Gaston Gas and Mining Co	L. F. Miller	Gaston.
Greenstreet Gas Co	G. A. Buckles	Albany.
Harrison Tp. Natural Gas Co	S. H. Jackson	Stout.
Jake's Creek Valley Gas Co	H. J. McClellan	Muncie.
Manufacturers' Fuel Gas Co	Bert Whitely	Muncie.
Manufacturers' Natural Gas Co	Frank Ball	Muncie.
Maple Grove Natural Gas Co	R. L. Brent	Eaton.
Manufacturers' Cöoperative Natural Gas Co	L. N. Dixon	Daleville.
Mt. Pleasant Natural Gas and Oil Co	Henry Slagel	Daleville.
Muncie Cöoperative Gas Co	John C. Eiler	Muncie.
New Burlington Natural Gas Co	J. B. Jackson	New Burlington.
Niles Natural Gas Co	D. B. Moore	Dunkirk.
No Name Natural Gas Co	W. T. Clark	Cowan.
North Muncie Farmers' Natural Gas Co	J. L. Powers	Muncie.
Oakville Natural Gas Co	Henry Weber	Oakville.
Pikes' Peak Natural Gas Co	W. H. Shoemaker	Daleville.
Reed Station Natural Gas Co	Chas. Fuson	Reed Station.
Richmond Farmers' Natural Gas Co	Perry V. Stewart	Muncie.
Ross & Fullheart Gas Co	W. W. Ross	Muncie.
Royerton Natural Gas Co	Lee Scott	Royerton.
Selma Natural Gas Co.	N. E. Black	Selma.
Sugar Creek Natural Gas Co	Frank Pittenger	Selma.
The Cöoperative Fuel and Gas Light Co	G. W. Whiteman	Albany.
The Mutual Natural Gas Co.	S. F. McNett	Gaston.
The Petroleum, Natural Gas and Exploring Co	J. R. Stafford	Albany.
Walker Natural Gas and Oil Co	Jos. Dillow	Gilman.
Washington Tp. Farmers' Cöoperative Fuel and Gas Light Co	J. W Lambert	Gaston.
York Prairie Natural Gas and Mining Co.	J. S. Buckles	Yorktown.
Yorktown Natural Gas and Oil Co	Thos. Allen	Yorktown.

LIST OF NATURAL GAS COMPANIES—Continued.

COMPANY.	PRES. OR SECY.	P. O. ADDRESS.
FAYETTE COUNTY.		
Connersville Natural Gas Co	C. E. J. McFarland	Connersville.
GRANT COUNTY.		
Arcana Gas Co	Joshua Strange	Arcana.
Barren Creek Gas Co.	John H. Caskey	Fairmount.
Cart Creek Gas Co	O. J. Simmons	Jalapa.
Citizens' Gas Co	Will C. Jay	Gas City.
Citizens' Gas Co	E. E. Carpenter	Fairmount.
Citizens' Gas Co	B. F. Thompson	Swayzee.
Citizens' Gas Co	Chas. E. Coffin	Marion.
Deer Creek Mining Co.	C. E. Carey	Hackleman.
Dry Fork Gas Co.	Con. L. Shugart	Marion.
Fairmount Mining Co	C. R. Small	Fairmount.
Fowler Gas Co	J. S. Fowler	Fowler.
Farmington Mining Co	Cary Carroll	Farmington.
Hackleman Mining Co.	Eli Goodwin	Marion.
Haw Run Gas Co	Abraham Small	Roseburg.
Herbst Natural Gas and Mining Co	T. J. Thompson	Herbst.
Jadden Gas Co	Isaiah Wall	Jadden.
Jonesboro Mining Co	R. M. Johnson	Jonesboro.
Lake Branch Mining Co	Timothy Forehand	Upland.
Landesville Gas Co	W. W. Sandess	Landesvjlle.
Michaels' Natural Gas Co.	Robert L. Smith	Michaels.
Mississinewa Mining Co	James F. Gabby	Marion.
New Cumberland Mining and Gas Co	Michael Cory	New Cumberl'nd.
North Marion Gas Co	Geo. B. Winchel	Marion.
Peoples' Gas Co.	James F. Gabby	Marion.
Pipe Creek Natural Gas Co.	Jos. W. Farley	Roseburg.
Roseburg Natural Gas Co	M. Drukemiller	Roseburg.
Swayzee Mining Co	John Reed	Swayzee.
Sweetser Mining Co	Geo. Williamson	Sweetser.
Triumph Gas Co	J. W. Cox	Fairmount.
Sweetser Natural Gas Co	Frank W. Chase	Sweetser.
The Upland Mining Co	Jacob Bugher	Upland.
West Marion Citizens' Gas Co	Jonathan Mills	Marion.
HANCOCK COUNTY.		
California Natural Gas Co	J. M. Henry	Maxwell.
Charlottesville Natural Gas Co	W. H. H. Rock	Charlottesville.
Citizens' Natural Gas Co	J. L. Fry	Greenfield.
Cleveland Natural Gas Co	Isaiah Manden	Cleveland.
Cushman Natural Gas Co	J. F. Cushman	Fortville.
Don's Natural Gas Co	H. C. Davis	Fortville.
Farmers' Natural Gas Co	John D. Cory	McCordsville.
Fortville Natural Gas Co	W. C. VanLaningham	Fortville.
Gilboa Natural Gas Co	J. E. Sample	Cleveland.
Greenfield Natural Gas Co	J. H. Can	Greenfield.
Haskett Ford Natural Gas Co		Carthage.
Independence Natural Gas Co	H. N. Bannett	Greenfield.
Maxwell Natural Gas Co	J. H. Mugg	Maxwell.
McCordsville Natural Gas Co	J. P. McCord	McCordsville.
Mohawk Natural Gas Co	A. O. Steele	Mohawk.
Morristown Natural Gas Co	L. E. McDonald	Morristown.
Mutual Natural Gas Co	D. B. Cooper	Greenfield.
Nameless Creek Natural Gas Co	C. M. Vanderbark	Cleveland.
National Natural Gas Co	M. T. Duncan	Greenfield.
Pigeon Roost Natural Gas Co	J. M. McKown	Charlottesville.
Pleasant Hill Natural Gas Co	E. Tijner	Greenfield.
Scrabbletown Natural Gas Co	Moses Bates	Wilkinson.
Stringtown Natural Gas Co	George W. Crider	Greenfield.
Sugar Creek Natural Gas Co	J. C. Webber	Greenfield.
T. J. Hannah Natural Gas Co	T. J. Hanna	McCordsville.
Vernon Natural Gas Co	G. S. Williams	Fortville.
Westerngrove Natural Gas Co	Joseph L. Binford	Westland.
Westland Natural Gas Co	L. Wiggins	Westland.
Wilkinson Natural Gas Co	Benjamin H. Cook	Wilkinson.
Willow Branch Natural Gas Co	Henry Marsh	Willow.

LIST OF NATURAL GAS COMPANIES—Continued.

Company.	Pres. or Secy.	P. O. Address.
HAMILTON COUNTY.		
Atlanta Natural Gas Co	J. M. Whistler	Atlanta.
Bakers' Corner Natural Gas Co	J. B. Foulk	Bakers' Corner.
Bethlehem Natural Gas and Oil Co	H. L. Dick	Cicero.
Big Springs Natural Gas Co	W. T. Billings	Big Springs.
Buffalo Corner Natural Gas Co	Henry Sowers	Arcadia.
Carmel Natural Gas Co	L. G. Small	Carmel.
Central Gas Co	S. M. Smith	Westfield.
Cicero Natural Gas Co	Wm. Z. Colling	Cicero.
Citizens' Natural Gas Co	Z. T. Hobbs	Atlanta.
Citizens' Natural Gas and Oil Co	S. D. Stultz	Jolietville.
Clay Center Natural Gas Co	O. C. Elliott	Carmel.
Clarksville Natural Gas Co	John Passwater	Clarkville.
County Line Gas and Oil Co	Cal Faussett	Fortville.
Eagletown Pioneer Gas Co	P. F Brunson	Eagletown.
Eureka Natural Gas and Oil Co	T. A. Stephens	Eagletown.
Fall Creek Township Natural Gas Co	Gus Brooks	Fishers' Switch.
Farmer's Natural Gas Co	R. M. Johnson	Arcadia.
Federal Hill Natural Gas Co	Calvin Keesling	Noblesville.
Fisher's Switch Natural Gas Co	I. P. Heath	Fishers' Switch.
Hortonville Natural Gas Co	J. A. Aldred	Hortonville.
John Harrison Natural Gas Co	John Harrison	Noblesville.
Keck Natural Gas Co	W. A. Hill	Omega.
Little Eagle Natural Gas Co	M. Stultz	Eagletown.
Noblesville Gas and Improvement Co	C. R. Davis	Noblesville.
Nora Natural Gas Co	R. Moffitt	Nora.
Northwestern Natural Gas Co	Geo. Stultz	Zionsville.
Olio Natural Gas and Oil Co	W. A. Young	Olio.
Pleasant Valley Natural Gas Co	N. C. Shaw	Fortville.
Poplar Ridge Natural Gas Co	J. H. Harvey	Carmel.
Sheridan Natural Gas Co	H. J. Thistlewait	Sheridan.
Slabtown Natural Gas Co	J. E. West	Waugh.
Spicewood Natural Gas Co	O. C. Lindley	Sheridan.
Stoney Creek Natural Gas Co	T. A. Rambo	Noblesville.
Stoney Creek Natural Gas Co. No. 2	Marion Smith	Clarksville.
Strawtown Natural Gas Co	W. W. Morris	Strawtown.
Tile Factory Corner Natural Gas Co	A. H. Bray	Noblesville.
Westfield Gas and Milling Co	A. L. Binford	Westfield.
White River Natural Gas Co	C. D. Zimmer	Strawtown.
HENRY COUNTY.		
Cadiz Natural Gas Co	A. L. Alshouse	Cadiz.
Central Natural Gas Co	W. W. Horston	Cadiz.
Citizens' Natural Gas Co	A. E. Sample	Knightstown.
Citizens' Natural Gas Co	G. L. Swan	Middletown.
Dunreith Natural Gas Co	J. W. Hayes	Dunreith.
Enterprise Natural Gas Co	J. I. Morris	New Castle.
Farmers' Free Gas Co	J. L. Hartly	Mt. Summitt.
Farmers' Natural Gas Co	John Wilkinson	Middletown.
Farmers' Natural Gas Co	E. B. Raddiff	Spiceland.
Gronendyke Gas Co	James Gronendyke	Middletown.
Honey Creek Natural Gas Co	John Starkey	Honey Creek.
Kennard Natural Gas Co	A. J. Daniels	Kennard.
Knightstown Natural Gas Co	Thomas B. Deem	Knightstown.
Mechanicsburg Natural Gas Co	S. M. Keesling	Mechanicsburg.
Montgomery Creek Natural Gas Co	J. B. Modlin	Greensboro.
Moreland Natural Gas Co	A. B. Shepherd	Moreland.
Ogden Natural Gas Co	J. A. Moffette	Ogden.
Painters Plain Natural Gas Co	Cyrus Vanmeter	Middletown.
Spiceland Natural Gas Co	E. A. Bogue	Spiceland.
Stone Quarry Natural Gas Co	S. J. Tright	Greensboro.
Sulphur Springs Natural Gas Co	Jacob Good	Sulphur Springs.
Walnut Level Natural Gas Co	Samuel Bowers	Cadiz.
Welcome Natural Gas Co	Edward Lewis	Knightstown.
HOWARD COUNTY.		
Pittsburgh Plate Glass Co	H. G. Chisnell	Kokomo.
Flabby Natural Gas Co	John W. Phares	Plevna.
Greentown Natural Gas Co	H. A. Covalt	Greentown.
Howard Natural Gas, Oil, Mining and Pipe Line Co	J. K. Saul	Sycamore.
Liberty Natural Gas Co	C. E. Leeson	Plevna.
Manufacturers' Pipe Line Co	J. M. Leach	Kokomo.
Sycamore Natural Gas Co	Abe Garr	Sycamore.
Kokomo Natural Gas and Oil Co	G. W. Landon	Kokomo.

LIST OF NATURAL GAS COMPANIES—Continued.

Company.	Pres. or Secy.	P. O. Address.
HUNTINGTON COUNTY.		
Huntington Light and Fuel Co	F. D. Townsend	Huntington.
Warren Natural Gas Co	C. H. Good	Warren.
JAY COUNTY.		
Citizens' Natural Gas and Oil Co	J. L. Fulton	Portland.
Dunkirk Natural Gas and Oil Co	C. W. Smalley	Dunkirk.
Pennville Natural Gas and Oil Co	Samuel Mason	Pennville.
Portland Natural Gas and Oil Co	J. G. Crowell	Portland.
Red Key Natural Gas Co	J. D. S. Neeley	Lima, Ohio.
Richmond Natural Gas and Oil Co	Edgar Fishback	Redkey.
MADISON COUNTY.		
Adams Township Natural Gas and Oil Co		Markelville.
Alexandria Mining and Exploring Co	J. M. Tomlinson	Alexandria.
Alfont Natural Gas and Oil Co		Alfont.
Anderson Fuel and Supply Co.	G. C. Forry	Anderson.
Bear Creek Natural Gas Co	I. C. Peck	Perkinsville.
Canal Natural Gas Co		Alexandria.
Citizens' Natural Gas Co	J. H. Millspaugh	Anderson.
Citizens' Natural Gas and Mining Co	Bert Carpenter	Elwood.
Citizens' Natural Gas Co	Cyrus Spears	Summitville.
County Line Gas Co		Pendleton.
County Line Natural Gas and Oil Co		Ingalls.
Depauw Plate Glass Co	J. F. Merker	Alexandria.
Dyars Creek Gas and Oil Co	G. B. Carpenter	Lapel.
Elwood Natural Gas and Oil Co	W. G. Curtis	Elwood.
Fall Creek Gas Co	W. W. Williams	Pendleton.
Farmers' Mutual Natural Gas Co		Summitville.
Fosters Branch Natural Gas Co	A. C. Anderson	Pendleton.
Green Township Natural Gas Co		Pendleton.
Gilman Natural Gas Co		Gilman.
Hardman Natural Gas and Oil Co	Frank Mosely	Markelville.
Jacobs Natural Gas Co		Pendleton.
Lapel Natural Gas and Oil Co	J. R. Woodard	Lapel.
Markelville Natural Gas and Oil Co	W. H. Hardy	Markelville.
Mendon Natural Gas Co		Mendon.
Pendleton Natural Gas Co	O. W. Brownback	Pendleton.
Perkinsville Natural Gas and Oil Co	J. B. Applegate	Perkinsville.
Philips Land and Gas Co	V. C. Quick	Alexandria.
Pleasant Valley Natural Gas Co	T. A. Baker	Pendleton.
Riverside Natural Gas Co		Alexandria.
Ryan Valley Natural Gas and Oil Co		Perkinsville.
Scatterfield Natural Gas and Oil Co		Anderson.
Spring Valley Natural Gas Co	Liba Darlington	Pendleton.
Summitville Mining Co	O. E. Gordon	Summitville.
Victory Natural Gas and Oil Co	T. M. Moore	Summitville.
West Alexandria Natural Gas Co	S. C. Dalrymple	Alexandria.
MARION COUNTY.		
Consumers' Gas Trust Co	Bement Lyman	Indianapolis.
Indianapolis and Broad Ripple Natural Gas Co.	R. C. Light	Indianapolis.
Indianapolis Natural Gas Co	J. R. Pearson	Indianapolis.
Manufacturers' Natural Gas Co	H. McK. Landon	Indianapolis.
United States Encaustic Tile Natural Gas Co.	John Pickens	Indianapolis.
MIAMI COUNTY.		
Amboy Natural Gas Co.	C. P. Baldwin	Amboy.
Citizens' Gas and Pipe Line Co	H. Bouslog	Peru.
North Grove Natural Gas Co	J. E. Marsh	Peru.
West Xenia Real Estate, Gas and Pipe Line Co	A. C. Smith	Converse.
Xenia Natural Gas and Pipe Line Co	Aaron Michaels	Converse.

LIST OF NATURAL GAS COMPANIES—Continued.

Company.	Pres. or Secy.	P. O. Address.
RANDOLPH COUNTY.		
Citizens' Natural Gas Co	I. C. Mills	Parker.
Eastern Indiana Oil and Gas Co	Ed. Goodrich	Union City.
Elkhorn Natural Gas Co	John Nixon	Farmland.
Farmland Natural Gas Co	J. H. Thornburgh	Farmland.
Green Township Natural Gas Co	Jacob Life	Shedville.
Lynn Natural Gas Co	J. S. Blair	Lynn.
Parker Natural Gas Co	L. A. Botkin	Parker.
Rock Oil Co	E. F. Kitselman	Winchester.
Windsor Natural Gas Co	Milo Davidson	Windsor.
Ridgeville Natural Gas Co		Ridgeville.
RUSH COUNTY.		
Big Four Natural Gas Co		Carthage.
Carthage Natural Gas Co	O. S. Hill	Carthage.
Citizens' Natural Gas Co		Manilla.
Cream Ridge Natural Gas Co.		Carthage.
Farmers' Natural Gas Co		Mays.
Five Points Natural Gas Co		Sexton.
Hack eman Natural Gas Co		Mays.
Homer Natural Gas Co.		Homer.
J. B. Kirkpatrick Natural Gas Co		Sexton.
Manilla Natural Gas Co		Manilla.
Mays Station Natural Gas Co		Mays.
People's Natural Gas Co	J. Q. Thomas	Rushville.
Riverside Natural Gas Co	John White	Rushville.
Rushville Natural Gas Co	Wm. J. Henley	Rushville.
Sexton Natural Gas Co		Sexton.
Walnut Ridge Natural Gas Co		Carthage.
Walnut Street Natural Gas Co		Carthage.
W. L. Walker Natural Gas Co		Carthage.
SHELBY COUNTY.		
Citizens Natural Gas Co	J. L. Showers	Shelbyville.
Fountaintown Natural Gas Co	H. M. Inlow	Fountaintown.
Morristown Natural Gas Co	L. E. McDonald	Morristown.
Southern Indiana Natural Gas Co.	P. G. Kamp	Shelbyville.
Waldron Natural Gas Co		Waldron.
TIPPECANOE COUNTY.		
Lafayette Natural Gas and Oil Co	S. T. Murdock	Lafayette.
TIPTON COUNTY.		
Citizens' Natural Gas Co	J. C. Urmston	Tipton.
Citizens' Natural Gas Co	J. R. Hildrup	Windfall.
Lutz Natural Gas Co	J. C. Lutz	Goldsmith.
Tipton Line and Improvement Co	John Kemp	Tipton.
Tipton Light, Heat and Power Co	Peter McArdle	Tipton.
Vanbrigle Natural Gas Co	Peter Vanbrigle	Groomsville.
Windfall Natural Gas, Oil and Mining Co	B. F. Legg	Windfall.
WABASH COUNTY.		
LaFontaine Natural Gas and Oil Co	O. H. Mason	LaFontaine.
Somerset Natural Gas Co	C. E. Henley	Wabash.
Wabash Fuel Co	M. H. Mendenhall	Wabash.
WAYNE COUNTY.		
Hagerstown Natural Gas Co	J. M. Hartley	Hagerstown.
Richmond Natural Gas Co	E. G. Hibbard	Richmond.
MISCELLANEOUS.		
Central Contract & Finance Co	J. D. S. Neely	Lima, Ohio.
Indiana Natural Gas and Oil Co	J. S. Smith	Chicago, Ill.
Logansport & Wabash Valley Natural Gas Co	S. T. Murdock	Lafayette.

OFFICE OF INSPECTOR OF MINES,
BRAZIL, IND., Jan. 16, 1895.

W. S. Blatchley, State Geologist:

DEAR SIR—I herewith transmit to you, as required by law, my annual report as Inspector of Mines for the State of Indiana. It embraces all matters required by law to be reported, as fully as possible with the material furnished in the reports furnished by operators and from the personal investigation of myself and assistants.

Respectfully,

ROBERT FISHER,
Inspector of Mines.

By the statistical tables given it will be seen that the number of mines in the State employing ten or more men is 106; the men employed in and about the mines, 7,885; mules used in the mines embraced in the report, 679; the total amount of coal of all kinds produced by such mines, 4,202,084 tons, to which is added an estimated amount produced by small mines of 110,000 tons, making a total of 4,312,084 tons. The estimated capital invested in the coal business in the State, exclusive of coal lands, is $1,852,500.

This shows an increase of production amounting to 664,851 tons, and is exceeded by only the years 1892 and 1893, in the history of coal production of the State. The large increase from last year is accounted for by the comparative absence of labor troubles during the year.

LABOR DIFFICULTIES AND CONDITION OF THE COAL TRADE.

During the months of January and February, as will be seen by reference to the table of the output of coal for the year by months, the mines were in active operation in all the coal producing counties, and were fairly well employed during March and April. As it had been customary for several years to arrange the yearly wage scale to take effect on May 1, the large falling off during May is to be partially attributed to the fact that stocks had been increased in anticipation of a more or less serious stoppage of the mines about that time. By mutual concessions this was avoided over the greater part of the State. On the failure of a conference of operators and miners to formulate a national scale of prices to be paid for mining in the various localities, the National officers of the United Mine Workers' Organization recommended that each mining district endeavor to make a scale agreeable to itself rather than to repeat the attempt of 1894 to bring about a suspension of work in all the coal fields of the country for the enforcement of a national scale of prices The condition of the coal trade at that time seemed to be such, that while a temporary reduction from last year's prices was inevitable, the upward tendency of all kinds of business gave promise that, within what is known as the scale year, *i. e.*, before May 1, 1896, prices would certainly advance to a degree that would justify even a higher price for mining than was then in force. The miners and operators of the Block Coal District met by committees, and on April 27, 1895, arrived at an agreement by the terms of which the standard price for mining was to be the same as for 1894–5, but that in certain contingencies the miners were to accept a reduction of not to exceed 5 cents per ton, and work was continued at this rate until June 15, when, by agreement, the price per ton of screened coal was reduced to 65 cents and other work in and about the mines in the same proportion. This rate continued until October 1, when the standard price of 70 cents per ton was restored. As far as I have been able to learn no troubles of any consequence have occurred between operators and miners at any of the block coal mines during the year. Since November 1st nearly all the mines have been running full time, and the year closes with excellent promise for the immediate future.

The final settlement of a price for mining was not so easily nor speedily arrived at in the BITUMINOUS DISTRICT, from a complication of causes. The price paid during the scale year of 1894–5 in this district was based on the payment of sixty cents per ton for screened coal, but at some places all coal taken out of the mine is weighed before being screened (as is required by statute), and in others some is weighed in that way and some after being screened. A good deal of dissatisfaction existed among the miners over this state of affairs, and an effort was made to arrange a scale based on the price to be paid for "mine run" or unscreened coal. The operators objected to making the change at that time. One of their number, Joseph Martin, Superintendent of the Parke County Coal Company, had been fined in the Parke Circuit Court for violation of the statute requiring coal to be weighed before screening, and had appealed the case to the Supreme Court, and they desired to wait for a final decision of that case before making the necessary changes in their arrangements for handling coal, so that they could comply with the statute.

The condition of the coal trade noted above made the miners averse to entering into a contract fixing the price for a year at any figure, and they were unalterably opposed to a reduction, even temporarily, below the sixty cent rate. The price was finally fixed at that rate to continue until July 15th, and work was continued under this agreement everywhere in the district except at the mines in Vermillion County. The operators there claimed that the nature of the competition they encountered would not permit them to pay this price, and demanded a reduction to fifty-five cents per ton. The miners refused to accept and a strike ensued, which lasted, with slight interruptions, until about November 1st, and was finally ended by the defeat of the miners and the refusal of the operators to treat with, or in any way recognize, the miners' organization. The price being paid there now is fifty-five cents.

At the expiration of the agreement on July 15th, the operators tried to secure a reduction of five cents per ton, finally offering to compromise by restoring it on October 1st. This was rejected by the miners, resulting in a strike at all the bituminous mines, from the B. & O. S W. Railroad northward except a few in Sullivan County which continued to pay the sixty cent rate. After several unsuccessful attempts to get those operators to join in a refusal to pay that rate the difficulty was finally adjusted by the operators conceding the demands made by the miners, and work was resumed at the old rate with the exception above noted. Since that time there have been some local troubles at the mines of the

TABLE No. 1.

Table showing the yearly production of coal for the State of Indiana from 1879 to 1895, inclusive.

YEAR.	TONS.	CAPITAL.	INSPECTOR.
Oct., 1879, to Oct., 1880	1,996,490	$1,135,562	Richards.
1881	1,771,536	1,442,210	Wilson.
1882	*	....	Wilson.
1883	2,560,000	1,600,000	Wilson.
1884	Est. 2,260,000	1,750,000	Wilson.
1885	2,375,000	1,850,000	McQuade.
1886	Est. 3,000,000	1,975,000	....
1887	3,140,979	....	McQuade.
1888	*		....
1889	3,676,000	2,081,000	....
1890	*		Tislow.
1891	3,819,600	New. 185,000	McQuade.
1892	4,494,811	No est.	McQuade.
1893	4,358,897	No est.	McQuade.
1894	3,440,353	No est.	McQuade.
1895	4,312,084	1,852,500	Fisher.

*No Report on file.

TABLE No. 2.

Table showing the number of mines, men employed, mules employed and estimated amount of coal produced and capital invested in the coal business in the State of Indiana, by counties:

	Mines.	Men.	Mules.	Production.	Capital.
Clay	32	3,076	180	1,334,436	700,000
Daviess	5	363	48	183,842	125,000
Fountain	3	80	8	20,687	27,000
Greene	6	692	59	336,740	175,000
Knox	3	60	4	25,895	37,500
Owen	1	22	3	5,706	10,000
Parke	14	1,213	108	585,941	300,000
Perry	2	60	8	16,819	23,000
Pike	4	484	40	227,033	115,000
Sullivan	11	720	87	433,204	275,000
Vanderburgh	6	309	35	167,185	110,000
Vermillion	5	200	24	176,434	115,000
Vigo	11	544	53	532,094	200,000
Warrick	3	62	12	67,748	45,000
	106	7,885	679	4,202,084	1,852,500

The estimate of capital above given does not include investments in coal lands.

TABLE No. 3.

Table showing the amount of coal produced in the State during the year 1895, by months:

January	534,173
February	443,186
March	338,897
April	332,999
May	133,914
June	190,298
July	239,800
August	248,060
September	258,158
October	437,275
November	539,812
December	505,527
Total	4,202,084
Small mines—estimate	110,000
Grand total	4,312,084

The estimate for small mines is made on the basis of reports from thirty-five of that class located in different parts of the State, and the names of persons operating mines furnished me, but who have not reported their output.

TABLE No. 4.

List of Mine Bosses.

Mine.	Boss.	Address.
CLAY COUNTY.		
Brazil B. C. Co., No. 1	John Bolin	Brazil.
Brazil B. C. Co., Gart. No. 3	Wm. Conroy	Brazil.
Brazil B. C. Co., Gart. No. 5	Andrew Gilmore	Cardonia.
Brazil B. C. Co., Gart. No. 6	John Mushett	Brazil.
Brazil B. C. Co., Gart. No. 8	Robt. J. Wallace	Diamond.
Brazil B. C. Co., Gart. No. 10	James Donehay	Brazil.
Brier Hill	Robt. Bennie	Clay City.
Harrison, No. 2	Thos. Faulds	Clay City.
Gladstone	Henry Schlatter	Brazil.
Pratt	H. W. Jenkins	Perth.
Crawford, No. 2	Walter Knox	Asherville.
Crawford, No. 5	Wm. Penze	Hoosierville.
World's Fair	John Scott	Knightsville.
Diamond, No 3	Thomas McQuade	Perth.
Fortner	Ellsworth Tibbitts	Turner.
Excelsior	H. B. Ehrlich	Brazil.
Superior Bituminous	Jacob Ehrlich	Turner.
Eureka, No. 1	S. J. Wilton	Carbon.
Eureka, No. 2	Thomas Dalton	Carbon.
Nickel Plate	John Cox, Sr.	Brazil.
Brazil	Moses Marks	Cardonia.
McIntosh, No. 2	Wm. L. Wallace	Brazil.
Monarch	James King	Brazil.
Nellie	David J. Evans	Brazil.
Fairview	Wm. J. Price	Cardonia.
San Pedro	Ed. Somers	Staunton.
Gartside	James Cuthbertson	Cardonia.
Louise	Wm. Parker	Center Point.
American Beauty	Thomas Thompson	Hoosierville.
Brier Hill	Mike Hofman	Asherville.
Columbia	George Myers	Knightsville.

TABLE No. 4—Continued.

Mine.	Boss.	Address.
Daviess County.		
Cable, No. 4	A. Kocher	Washington.
Cable, No. 9	Gus Wellinger	Washington.
Montgomery	George B. Brown	Montgomery.
Mutual	M. Cahill	Cannelburgh.
Wilson		Washington.
Stoy	A. W. Stucky	Raglesville.
Fountain County.		
Indiana Bituminous, No. 2	Steward Shirkie	Silverwood.
Shipman	J. N. Dexter	Silverwood.
Sturm	J. S. Tiley	Silverwood.
Greene County.		
Island, No. 1	S. C. Risher	Linton.
Island, No. 2	Virgil Robertson	Linton.
Island, Valley	Joe Fennel	Linton.
Fluhart	James B. Palmer	Linton.
South Linton	Joseph Ferry	Linton.
Summit	Frank Lockhart	Linton.
Knox County.		
Bicknell	R. M. Freeman	Bicknell.
Prospect Hill	Joseph Drovetta	Vincennes.
Edwardsport	Richard Geade	Edwardsport.
Gibson County.		
Francisco	J. W. Robbs	Francisco.
Oakland City	Fred Cotterill	Oakland City.
Owen County.		
Lancaster, No. 4	James F. Andrews	Woodside.
Parke County.		
Cox, No. 3	George A. Davis	Coxville.
Otter Creek	J. D. Lewis	Carbon.
Crawford, No. 1	Wm. Spears	Brazil.
I. McIntosh, No. 1	John Schlatter	Brazil.
Mecca, No. 1	James Skene	Mecca.
Mecca, No. 2	Morgan Roberts	Mecca.
Parke, No. 6	I. H. Valentine	Rosedale.
Parke, No. 7	Wm. Gatt	Odd.
Parke, No. 8	George Mitch	Rosedale.
Parke, No. 10	I. N. Williams	Rosedale.
Superior, No. 1	C. E. Peck	Diamond.
Superior, No. 2	John Chesterfield	Brazil.
Lyford, No. 1	J. C. Martin	Lyford.
Lyford, No. 2		Lyford.
Perry County.		
Cannelton	George W. Briggs	Cannelton.
Troy	Bergenroth Bros	Troy.
Pike County.		
Hartwell	Thomas Small	Augusta.
Ayrshire	John Jennings	Ayrshire.
Blackburn		
Littles	Andrew Dodds	Littles.
Spencer County.		
Schafer	Henry Schafer	Lincoln City.
Romine	J. Romine	Gentryville.

TABLE No. 4—Continued.

Mine.	Boss.	Address.
SULLIVAN COUNTY.		
Bush Creek	H. W. Robertson	Farnsworth.
Dugger Coöperative	R. W. Evans	Dugger.
Bunker Hill	Harry Conkel	Farnsworth.
Star City	John McCloud	Shelburn.
Dugger	H. A. Butler	Dugger.
Jumbo	W. E. Evans	Eagle.
Currysville	C. C. Hall	Shelburn.
Phenix, No. 1	Wm. F. Brown	Alum Cave.
Old Pittsburg	John McAnally	Hymera.
Shelburn	Thomas Thomas	Shelburn.
VANDERBURGH COUNTY.		
Diamond	Wm. Horst	Evansville.
Union	Pius Schultheis	Evansville.
First Avenue	Louis M. Gaisser	Evansville.
Ingleside	John O'Dell	Evansville.
Sunnyside, No. 1	Henry Baetz	Evansville.
Sunnyside, No. 2		
VERMILLION COUNTY.		
Hazel Creek, No. 1	Dexter Vannest	Clinton.
Fern Hill	F. P. Christy	Clinton.
Indiana Bituminous, No. 1	Stewart Shirkie, Sr.	Clinton.
Torrey, No. 4	W. H. Robertson	Voorhees.
VIGO COUNTY.		
Diamond	Charles Nash	Coal Bluff.
Peerless	G. R. Anthony	Fontanet.
Star	Thomas Gregory	Fontanet.
Union	Jas. Johnson	Fontanet.
Victor	C. R. McGrannahan	Fontanet.
Eagle	Ed Davis	Fontanet.
Nickel Plate	Peter Andrew	Terre Haute.
Seeleyville		
Grant	J. L. Devonald	Burnett.
Vigo	John W. Alvis	Kanawha.
Ray	Wm. Grey	Seeleyville.
WARRICK COUNTY.		
Star	George Archbold	Newburg.
Lauder	Wm. Wooley	Boonville.

TABLE No. 5.

Table showing names and addresses of operators of mines employing more than ten men, with the names of the mines, showing new mines opened during the year and those suspended and abandoned.

CLAY COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
Brazil Block Coal Co	Brazil, Ind	Brazil Block, No. 1	1			
Brazil Block Coal Co	Brazil, Ind	Gartsherrie, No. 4		1		1
Brazil Block Coal Co	Brazil, Ind	Gartsherrie, No. 5		1		
Brazil Block Coal Co	Brazil, Ind	Brazil Block, No 6		1		
Brazil Block Coal Co	Brazil, Ind	Brazil Block, No. 8		1		
Brazil Block Coal Co	Brazil, Ind	Brazil Block, No. 9				1
Brazil Block Coal Co	Brazil, Ind	Brazil Block, No. 10		1	10m	
Brazil Brick and Pipe Co	Brazil, Ind	B. and P. Co	1			
Briar Block Coal Co	Clay City, Ind	Briar Hill		1		
Chicago and Indiana Coal Co.	Terre Haute, Ind	Harrison		1		
Clay County Coal Co	Brazil, Ind	Gladstone		1		
Coal Bluff Mining Co	Terre Haute, Ind	Pratt		1		
Crawford Coal Co	Brazil, Ind.	Crawford, No. 2		1		
Crawford Coal Co	Brazil, Ind	Crawford, No. 5				1
D. H. Davis Coal Co	Knightsville, Ind	World's Fair		1		
Diamond Block Coal Co	Chicago, Ill	Diamond ,No. 3		1		
Eureka Block Coal Co	Terre Haute, Ind	Eureka, No. 1		1		
Eureka Block Coal Co	Terre Haute, Ind	Eureka. No. 2		1		
Goucher, McAdoo & Co	Brazil, Ind	Monarch	1			
Jackson Coal Mining Co	Brazil, Ind	Brazil		1		
Jackson Coal Mining Co	Brazil, Ind	Nickel Plate		1		
C. Ehrlich Mining Co	Turner, Ind	Fortner		1		
C. Ehrlich Mining Co	Turner, Ind	Excelsior		1		
P. Ehrlich	Turner, Ind	Superior	1			
I. McIntosh & Co	Brazil, Ind	McIntosh, No. 2	1			
Otter Creek Coal Co	Brazil, Ind	Fairview		1		
Otter Creek Coal Co	Brazil, Ind	Nellie		1		
Watson, Little & Co	Brazil, Ind	Gartside		1		
Henry E. Weaver, Agt	Chicago, Ill	Louise		1		
Zeller & Sigler C. and M. Co	Knightsville, Ind	American Beauty		1		
Zeller & Sigler C. and M Co	Knightsville, Ind	Briar Hill		1		
Zeller & Sigler C. and M. Co	Knightsville, Ind	Columbia		1		
Jos. Somers	Staunton, Ind	San Pedro		1		

DAVIESS COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
Cabel & Co	Washington, Ind	Cabel, No. 4		1		
Cabel & Co	Washington, Ind	Cabel, No. 7			1	
Cabel & Co	Washington, Ind	Cabel, No. 9		1		
Cabel & Co	Washington, Ind.	Maple Valley			1	
Daviess County Coal Co	Montgomery, Ind	Montgomery		1		
Mutual Mining Co	Cannelburg, Ind	Mutual		1		
Washington Coal Co	Washington, Ind	Wilson's, No. 1		1		
Washington Coal Co	Washington, Ind	Wilson's, No. 2	1			
Abe Stoy	Odon, Ind	Stoy	1			
J. M. Winklepleck	Odon, Ind	Winklepleck	1			

FOUNTAIN COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
Indiana Bituminous Coal Co	Terre Haute, Ind	Shipman		1		
Indiana Bituminous Coal Co	Terre Haute, Ind	Silverwood, No. 2	1			
M. Sturm	Silverwood, Ind	Sturm		1		

GIBSON COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
Fred Cotterill	Oakland City, Ind	Oakland		1		
J. W. Robbs	Francisco, Ind	Francisco				1
Maule Coal Co	Princeton, Ind	Princeton	1			

GREENE COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
Island Coal Co	Indianapolis, Ind	Island, No. 1		1		
Island Coal Co	Indianapolis, Ind	Island, No. 2		1		
Island Valley Coal Co	Linton, Ind	Island Valley		1		
Linton Coal Co	Linton, Ind	Fluhart		1		
South Linton Coal Co	Linton, Ind	South Linton		1		
Summit Coal Co	Bloomfield, Ind	Summit		1		

KNOX COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
Bicknell Coal Co	Bicknell, Ind	Bicknell		1		
Hoffman Edwardsp't Coal Co.	Vincennes, Ind	Edwardsport	1			
Prospect Hill Coal Co	Vincennes, Ind	Prospect Hill		1		

OWEN COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
Lancaster Coal Co	Woodside, Ind	Lancaster, No. 3				1
Lancaster Coal Co	Woodside, Ind	Lancaster, No. 4	1			

PARKE COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
Brazil Block Coal Co	Brazil, Ind	Cox, No. 3		1		
Brazil Block Coal Co	Brazil, Ind	Otter Creek		1		
Calumet Coal Co	Chicago, Ill	Lyford, No. 1		1		
Calumet Coal Co	Chicago, Ill	Lyford, No. 2			1	
Crawford Coal Co	Brazil, Ind	Crawford, No. 1		1		
I. McIntosh & Co	Brazil, Ind	McIntosh, No. 1		1		
Otter Creek Coal Co	Brazil, Ind	Mecca, No. 1		1		
Otter Creek Coal Co	Brazil, Ind	Mecca, No. 2		1		
Parke County Coal Co	Rosedale, Ind	Parke, No. 6		1		
Parke County Coal Co	Rosedale, Ind	Parke, No. 7		1		
Parke County Coal Co	Rosedale, Ind	Parke, No. 8		1		
Parke County Coal Co	Rosedale, Ind	Parke, No. 9				1
Superior Block Coal Co	Brazil, Ind	Superior, No. 1		1		
Superior Block Coal Co	Brazil, Ind	Superior, No. 2	1			

PERRY COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
American Cannel Coal Co	Cannelton, Ind	Cannelton		1		
Bergenroth Bros	Troy, Ind	Troy		1		

PIKE COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
Cabel & Kaufman Coal Co	Washington, Ind	Hartwell		1		
D. Ingle	Oakland City, Ind	Ayrshire		1		
S. W. Little Coal Co	Evansville, Ind	Blackburn		1		
S. W. Little Coal Co	Evansville, Ind	Littles		1		

SULLIVAN COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
Dugger Coöperative Coal Co.	Dugger, Ind	Coöperative		1		
Ind. & Chicago Coal Co	Dugger, Ind	Dugger		1		
Hancock & Conkel	Farnsworth, Ind	Bunker Hill				
Jackson Hill Coal Co	Eagle, Ind	Jumbo		1		
New Pittsburgh C. and C. Co	Alum Cave, Ind	Phoenix, Nos. 1 and 2		1		
New Curryville Coal Co	Shelburn, Ind	Curryville		1		
Shelburn Mining Co	Shelburn, Ind	Shelburn		1		
Harder-Hafer Mining Co	Shelburn, Ind	Star		1		
Watson, Little & Co	Chicago, Ill	Bush Creek	1			

VANDERBURGH COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
Diamond Coal Co	Evansville, Ind	Diamond		1		
Evansville Union Coal Co	Evansville, Ind	Union		1		
First Avenue Coal Co	Evansville, Ind	First Avenue		1		
John Ingle Coal Co	Evansville, Ind	Ingleside		1		
Sunnyside Coal and Coke Co	Evansville, Ind	Sunnyside, No. 1		1		
Sunnyside Coal and Coke Co	Evansville, Ind	Unity		1		

VERMILLION COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
Indiana Bituminous Coal Co.	Terre Haute, Ind	Indiana Bituminous No. 1		1		
Hazel Creek Coal Co	Clinton, Ind	Fern Hill		1		
Hamilton, Vannest & Co	Clinton, Ind	Hazel Creek		1		
Torrey Coal Co	Voorhees, Ind	Torrey, No. 4		1		
McClelland, Eastman & Co	Clinton, Ind	Buckeye	1			

VIGO COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
Coal Bluff Mining Co	Terre Haute, Ind	Diamond, No. 1				1
Coal Bluff Mining Co	Terre Haute, Ind	Diamond, No. 2	1			
Coal Bluff Mining Co	Terre Haute, Ind	Hercules		1	1	
Coal Bluff Mining Co	Terre Haute, Ind	Peerless		1		
Coal Bluff Mining Co	Terre Haute, Ind	Star		1		
Coal Bluff Mining Co	Terre Haute, Ind	Victor		1		
Ed Davis Mining Co	Fontanet, Ind	Eagle	1			
J. Ehrlich	Seeleyville, Ind	Seeleyville			1	
Ehrman Coal Co	Terre Haute, Ind	Nickel Plate		1		
Grant Coal Co	Burnett, Ind	Grant		1		
Parke County Coal Co	Rosedale, Ind	Parke, No. 10		1		
Vigo Coal Co	Chicago, Ill	Vigo.	1			
Vigo County Coal Co	Seeleyville, Ind	Ray	1			

WARRICK COUNTY.

Owner.	Address.	Mine.	New.	Old.	Suspended.	Abandoned.
John Archbold	Evansville, Ind	Star		1		
Gough & Kelly	Boonville, Ind	Gough			1	
Howard-Jennings Co	Chandlers, Ind	Howard	1			
Clemens Vogt Coal Co	Evansville, Ind	Chandler			1	
Lauder-Wooley Coal Co	Evansville, Ind	Lauder		1		

RECAPITULATION.

County.	New.	Old.	Suspended.	Abandoned.	County.	New.	Old.	Suspended.	Abandoned.
Clay	5	24		3	Pike	1	4		
Daviess	3	5	2		Spencer			2	
Fountain	1	2			Sullivan	1	7	4	
Gibson	1	1		1	Vanderburgh		6		
Greene		5			Vermillion	1	4		
Knox	1	2			Vigo	4	6	1	2
Owen	1				Warrick	1	2	2	
Parke	1	11	1	1					
Perry		2			Totals	21	81	12	8

TABLE No. 6.

Table showing the amount of coal produced during the year 1895, by counties, by mines employing 10 or more men.

Clay	1,334,436
Daviess	183,842
Fountain	26,177
Greene	336,740
Knox	23,060
Owen	6,516
Parke	569,258
Perry	15,819
Pike	220,474
Spencer	2,803
Sullivan	453,807
Vanderburgh	209,469
Vermillion	191,626
Vigo	558,152
Warrick	69,905
Total	4,202,084

In addition to the above, I estimate the amount of coal of all kinds produced by mines employing less than ten (10) men at 110,000 tons. This estimation is based upon reports received from 35 of such mines.

TABLE No. 7.

Table showing the total amount of coal produced each month during the year 1895.

January	534,173	August	248,060
February	443,186	September	258,158
March	338,887	October	437,275
April	332,999	November	539,812
May	133,914	December	505,527
June	190,293		
July	239,800	Total	4,202,084

TABLE No. 8.

*Table showing the total output of each kind of coal at each mine in the State for the year 1895.**

CLAY COUNTY.

Mines.	Days.	Screened.	Slack.	Mine run.	Total.
American Beauty	156	29,032	6,845		35,877
Brazil, December estimate					23,199
Briar Hill	67	8,951	2,230		11,181
Briar Hill Block	203	17,198	7,242	2,025	26,465
Columbia	213	40,444	9,410		49,854
Crawford, No. 2	141	38,178	8,107	878	47,163
Crawford, No. 5	122	13,813	2,747	5,026	21,586
Diamond	194	58,940	18,485		77,425
Eureka, No. 1	137	33,319	7,484	4,280	45,083
Eureka, No. 2	122	51,749	13,407	10,630	75,795
Excelsior	185	25,115	11,023		36,138
Fortner	136	19,675	12,385		32,060
Fairview	184	35,262	77,245		42,507
Gladstone	187	25,687	5,020	23,216	53,923
Gartside	223	41,902	7,780		49,682
Gart., No. 1	275	25,825	4,897	516	31,238
Gart., No. 3	171	36,047	5,700		41,747
Gart., No. 4	141	15,928	2,140		18,068
Gart., No. 5	201	102,175	17,385	1,133	120,693
Gart., No. 6	238	28,134	6,610	1,271	36,015
Gart., No. 8	199	57,520	10,028	4,584	72,132
Gart., No. 9	51	3,094	510	587	4,191
Gart., No. 10	33	3,501	480		3,981
Harrison, No. 2	167	23,708	7,397	3,691	34,796
Louise, December estimate					46,386
McIntosh, No. 2	217	26,074	5,150		31,224
Nellie	204	14,048	3,270		17,318
Nickle Plate, December estimate					72,949
Pratt	194	32,135	6,079	14,159	52,373
San Pedro	215	45,941	23,704	90	69,735
Superior Bituminous	249	20,628	17,902		38,530
World's Fair	85	11,692	3,410		15,102
Totals		885,715	234,072	72,085	1,334,436

DAVIESS COUNTY.

Mines.	Days.	Screened.	Slack.	Mine run.	Total.
Cabel, No. 4	123	22,466	8,559		31,025
Cabel, No. 9	125	5,020	2,853	31,802	39,675
Mutual, December estimate					10,680
Montgomery	204	15,823	8,341	47,290	71,454
Montgomery, No. 2	76	3,768		7,690	11,458
Wilson	208	4,823	4,548	10,179	19,458
Totals		51,900	24,301	96,961	183,842

FOUNTAIN COUNTY.

Mines.	Days.	Screened.	Slack.	Mine run.	Total.
Silverwood, estimate					7,500
Sturm, estimate					10,000
Shipman		7,202	1,275		8,677
Totals		7,202	1,275		26,177

**Note.—All months are reported except those marked estimated.*

GREENE COUNTY.

Mines.	Days.	Screened.	Slack.	Mine run.	Total.
Fluhart, December Estimate					49,621
Island Valley	159	17,112	8,607	6,395	32,104
Island, No. 1, April to December Estimate					35,999
Island, No. 2, April to December Estimate					100,000
Summit	147	47,163	30,304	16,897	94,364
South Linton	124	16,814	8,807		25,651
Totals		81,119	47,718	23,282	336,740

KNOX COUNTY.

Bicknell	146	9,933	4,902	565	15,400
Prospect Hill	247	3,894	2,269	1,497	7,660
Totals		13,827	7,171	2,062	23,060

OWEN COUNTY.

Lancaster, No. 3	55	1,239	385		1,624
Lancaster, No. 4	144	3,723	1,169		4,892
Totals		4,962	1,554		6,516

PARKE COUNTY.

Crawford, No. 1	156	35,284	7,340		42,624
Cox, No. 3	135	686	103	66,748	67,537
McIntosh, No. 1	226	42,424	7,816		50,240
Mecca, No. 1	152	9,222	3,255	26,619	39,096
Mecca, No. 2	196	8,789	2,590		11,379
Parke, No. 6	155	70,217	23,013		93,230
Parke, No. 7	130	18,036	5,735		23,771
Parke, No. 8	170	34,622	11,943		46,565
Parke, No. 9	93	7,562	2,829		10,391
Otter Creek	225	13,953	2,099	578	16,630
Superior, No. 1	170	67,615	15,155		82,770
Superior, No. 2	108	7,453	1,770		923
Wabash, No. 1, December Estimate					75,802
Totals		315,863	83,648	93,945	569,258

PERRY COUNTY.

Camelton	22	2,884	1,006	5,451	9,341
Bergenroth	117			6,478	6,478
Totals		2,884	1,006	11,929	15,819

PIKE COUNTY.

Ayrshire	202	54,398	38,865	36,508	129,771
Hartwell	176	4,029	4,780	12,383	21,192
Little's	180	9,887	26,972	32,652	69,511
Totals		68,314	70,617	81,543	220,474

SPENCER COUNTY.

Mines.	Days.	Screened.	Slack.	Mine run.	Total.
Romine's					183
H. Schafer's	96	1,240	605	775	2,620
Totals		1,240	605	775	2,803

SULLIVAN COUNTY.

Alum Cave	216	5,526	9,878	90,233	105,637
Bunker Hill	157	9,420	5,200	1,674	16,294
Currysville	229	10,964	4,991	9,728	25,683
Dugger, December Estimate					57,931
Dugger Co-op., June to Dec. Estimate					5,184
Jumbo	172	71,982	38,338		110,320
Old Pittsburgh	1,317	28,192	2,838	7,601	38,631
Shelburn, No. 1	176	17,700	5,091	3,699	26,490
Shelburn, No. 2	26			991	991
Star City	183	44,264	11,900	5,392	61,556
Bush Creek	50	1,273		3,817	5,090
Totals		189,321	78,236	123,135	453,807

VANDERBURGH COUNTY.

Diamond	281	8,851	6,160	12,544	17,555
First Avenue, July to December Estimate					25,414
Ingleside, December Estimate					87,776
Sunnyside, No. 1	259	18,382	10,548	28,487	57,417
Sunnyside, No. 2	91			6,870	6,870
Union	258	7,948	3,140	3,349	14,437
Totals		35,181	19,848	41,250	209,469

VERMILLION COUNTY.

Fern Hill	132	53,818	21,707	906	76,431
Hazel Creek, Aug. to December Estimate					49,621
Indiana Bituminous, Mar. to Dec. Estimate	17			13,236	13,236
Torrey, No. 4	133	7,024	915	44,399	191,626
Totals		60,842	22,622	58,541	191,626

VIGO COUNTY.

Diamond, No. 1	92	6,383	2,620		9,003
Diamond, No. 2	61	3,089	1,410		4,499
Grant	193	35,856	28,410	16.540	80,806
Hercules	154	21,237	5,732	1,709	28,678
Nickel Plate, December Estimate					170,484
Peerless	118	9,445	4,769	3,083	17,297
Seeleyville	35	4,228	1,408		5,636
Star	194	29,142	10,565		39,707
Union	217	63,103	19,988		83,091
Victor	172	20,494	6,550		27,044
Vigo	218	18,380	12,105	8,543	39,928
Ray, December Estimate					42,476
Parke, No. 10	66	7,808	2,595		10,403
Totals		219,165	96,152	29,875	558,152

WARRICK COUNTY.

Mines.	Days.	Screened.	Slack.	Mine run.	Total.
Star	182	1,200	25,080		26,280
Lauder	226	2,410	41,215		43,625
Totals		3,610	66,295		69,905

NEW DEVELOPMENTS MADE DURING THE YEAR.

While quite a number of new mines have been opened during the year all except one have been in fields which have been partially developed heretofore. The shaft of the Maule Coal Co. at Princeton is an exception, however. After considerable difficulty on account of the soft strata which were encountered in the shaft, this company finally reached a vein of fine bituminous coal at a depth of 440 feet. It proved to be 6-ft. 10-in. in thickness and of excellent quality. The records of drill holes for gas wells indicate that the same vein underlies a large territory in the neighborhood of the city of Princeton. The Maule Company proposes to equip their shaft with first-class hoisting machinery, and a mining machine plant. The Yoch mining machine, driven by compressed air, will be used. Another shaft will be sunk during the coming summer and the prospects are bright for a large development in this field in the near future.

The development of the lower vein at Clinton and Geneva will tend to largely increase the output of coal from Vermillion County in the near future. Watson, Little & Co. have recently reached coal in a test shaft at Williamstown, Clay County, on the line which seems to divide the bituminous from the block coal fields and report the vein a good quality of bituminous with some of the properties of the block coal.

MINING MACHINERY.

My attention has been so fully occupied with other duties that I have been unable to give the question of mining by machinery in this State the attention it demands and consequently can not give the details of this branch of mining. During the year electric mining plants have been installed at the Brazil Block Coal Company's Mines, No. 1, in the city of Brazil and No. 8 on the line between Clay and Parke counties, in range 7. These are the only machines being used in the block coal field and it was so late in the year before their use passed the experimental stage that I have not data sufficient to base any predictions as to the extent to which they will probably be adopted in this field. At the close of the year there are at No. 1, 12 Morgan-Gardner machines, the power for which is furnished by two 75 Kilowatt dynamos, and at No. 8, 5 Independent and 10 Morgan-Gardner machines, driven by two 100 Kilowatt dynamos. The intention is to use machines at the latter mine only in the bottom vein, all work in the upper vein being done by pick miners.

In the bituminous field machines are used in the following mines, the power employed being compressed air:

In Parke County, at Mecca, No. 1, Parke County Coal Company's Mines, Nos. 6, 7 and 8, and the Calumet Coal Company's Mine, No. 1, at Lyford

In Vermillion County, at the Torrey Coal Mine No. 4.

In Vigo County, at the Star and Peerless Mines of the Coal Bluff Mining Company; the Grant Mine and Parke County Coal Company's No. 10 Mine.

In Sullivan County, at Phœnix, Jumbo, Currysville, Shelburn and Dugger.

In Greene County at Island Nos. 1 and 2.

In Vanderburgh at Sunnyside mines Nos. 1 and 2.

In Warrick County at the Lauder Wooley mine.

Electric mining machines are in use at the Old Pittsburgh and Star mines in Sullivan County.

Rope haulage systems are in use at mines No. 6 and No. 8 of the Parke County Coal Co., in Parke County, Nos. 8 and 10 of the Brazil Block Coal Co., in Clay County, Island No. 1 and No. 2, in Greene Co., and the Ingleside mine in Vanderburgh County, and two electric motors are in use at the Old Pittsburgh mine in Sullivan Co.

MINES GENERATING FIRE DAMP.

There are but few mines in the State which generate light carburetted hydrogen ($C H_4$) in sufficient quantity to render the air explosive. By reference to the table of Causes of Accidents it will be seen that but two accidents have occurred from this cause during the year. Both of the injured men have brought suit for damages, and I content myself here with the statement made in the list of serious accidents. However, without special reference to those cases, I will say that I have learned in my inquiries that where this gas is found it is not unusual for miners, after the proper marks have been made by the "fire boss" to indicate its presence in their places, to attempt to "brush" the gas out themselves rather than lose time from work while waiting for the proper official to get around to do it. Aside from the lack of experience of miners generally with this gas, this is a dangerous practice from the fact that a naked light must be used in the work, and there is no means of learning when the place is clear without carrying that light into the place where the gas had been standing, when there is danger of an explosion if the work has not been properly done. Serious explosions have also occurred by "brushing" the gas back upon a naked light which had been left at a presumably safe distance from the point where the gas had been found lodged. The only safe rule is that no person should enter a working place where gas has been detected until it has been cleared by the proper person, and shown to be so by the safety lamp.

The following are the mines in which this gas has been found in dangerous quantities:

Mecca, No. 1, in Parke County.
McIntosh, No. 1, in Parke County. Lower vein.
Lyford, No. 1, in Parke County.
Gladstone, in Clay County.
Shelburn, in Sullivan County.
Currysville, in Sullivan County.
Howard-Jennings, in Warrick County.

OIL USED FOR ILLUMINATING PURPOSES.

One of the most difficult matters to deal with which is to be found in the mines of Indiana to-day is the inferior quality of the oil used for illuminating purposes. In several instances, on the first examination of mines, they being idle at the time, were found, when measured by the anemometer, to have sufficient ventilation in all parts for the number of men reported to be employed. On a subsequent visit, when the men were at work, with fully as good a current going the air was found loaded with a sickly smelling, heavy smoke, coming from the lamps used by persons at work in the mine. The impurities causing this smoke are principally the carbons of mineral oils used in adulterating the animal or vegetable oils which should be used. My observation is that this smoke is very difficult to move by any current that it is possible to produce in mines, especially where it accumulates in a dip or swamp, so that simply increasing the amount of air circulating in the mine would not remedy the evil. This question has engaged the attention of Mine Inspectors in the several States for years past, and some of them have succeeded in having laws passed making it a penal offense to use in the mines oils which have been so adulterated. I give herewith a copy of the Ohio statute on this subject, as amended, and would urge upon the Legislature of this State the passage of a similar law, with a penalty sufficient to insure compliance with its provisions.

OHIO PURE OIL LAW.

"Only a pure animal or vegetable oil, or other oil as free from smoke as a pure animal or vegetable oil, and not the product or by-product of rosin, and which shall, on inspection comply with the following test, shall be used for illuminating purposes in the mines of this state: All such oil must be tested at 60° Fahrenheit. The specific gravity of the oil must not exceed 24° Tagliabue. The test of the oil must be made in a glass jar one and five-tenths inches in diameter by seven inches in depth. If the oil to be tested is below 45° Fahrenheit in temperature it must be heated until it reaches about 80° Fahrenheit; and should the oil be above 45° and below 60° Fahrenheit it must be raised to a temperature of about 70° Fahrenheit, when, after being well shaken, it should be allowed to cool gradually to a temperature of 60° Fahrenheit, before finally being tested. In testing the gravity of the oil, the Tagliebue hydrometer must be, when possible, read from below, and the last line which appears under the surface of the oil shall be regarded as the true reading. In case the oil under test should be opaque or turbid, one-half of the capillary attraction shall be deemed and taken to be the true reading. Where the oil is tested under difficult circumstances, an allowance of one-half degree may be made for possible error in parallax before condemning the oil for use in the mine. All oil sold to be used for illuminating purposes in the mines of this State shall be contained in barrels or packages, branded conspicuously with the name of the dealer, the specific gravity of the oil, and the date of shipment."

In this connection I desire to say that my predecessor has in several of his annual reports called attention to this evil and recommended the passage of a law to prevent the sale and use of adulterated oil in the mines of the State. In the last Legislature a bill for such an act was introduced into the House of Representatives by Mr. O'Brien, of Clay County, and referred to the Committee on Mines and Mining. This committee was composed of members who, with one exception, had no personal experience in coal mines, and they could not believe that miners or other employes in mines would deliberately injure their health for the sake of saving a few cents per month in the cost of illuminating oil.

I will also say that from the time I took possession of my office until the present, I have had more complaints of this matter, and requests from both miners and operators to assist in securing the use of pure oil than of all other evils affecting the working of the mines. Several miners have told me that the use of impure oil has driven them to abandon work in the mines entirely on account of its effect upon their lungs, already affected with asthmatic troubles. After talking with one of these I visited a mine where his brother was at work and found him working in a cloud of smoke so thick as to make his light have the appearance of a blood red danger signal, all coming from the lamps of himself and his son. On remonstrating with him on using such oil and referring to his brother's case his reply was that it was no use for one to use good oil while others were using cheap oil. I then called his attention to the fact that the air was coming to him fresh from the fan and that if he had good oil, smoke from others would not trouble him. He said: "Ay, but this place winna last long, then I may ha' to go on the air ahint the oother." Compulsion by law is the only way to influence such men and they are numerous in the mines. While mine officials profess to be very anxious to have pure oil used by employes I have seen some of the worst oil I have met in the mines, being used by the mine bosses and drivers. A few mine bosses have taken the matter in hand and shown that where they are in earnest, even in the absence of a penal law, a reform can be effected. But there are so few of these, that the general result is unsatisfactory, and the passage of a law similar to that of Ohio seems to be the only adequate remedy.

MINES EXAMINED.

I give below a brief description of the condition of mines visited during the year, by myself and assistants.

CLAY COUNTY.

No. 1 MINE.

Owned by Brazil Block Coal Company. Located in the northwest part of the city of Brazil. Is a new mine and has been more or less out of proper condition during the year. The company have been experimenting here with electric mining machinery and the changes necessary in putting in, first the experimental plant, and afterwards the permanent plant have prevented the proper arrangement and development of the mine. It is now equipped with machines in successful operation, the first in the Block Coal field, and is in fair condition as regards ventilation. The escape shaft has been practically useless since it was finished on account of an accumulation of water in the road to it, but that has been lately removed. During the year an air and escape shaft has been sunk and a twelve-foot fan erected at this mine.

COLUMBIA MINE.

Zeller & Sigler Coal and Mining Co., located one-half mile southwest of Knightsville. The top vein, bad roof, wet roads, air courses in bad shape, and several doors broken down. Air bad in nearly all working places, though a good current was in nearly every case carried up to where working began. This is an old mine and work is a long way from the shaft. On a second visit I found the condition greatly improved and as the pillars are being drawn I think there will be little difficulty with air during the remaining time the shaft will be worked. It will probably be abandoned during 1896.

CRAWFORD No. 2 MINE.

Located at Center Point, Ind. I found this mine idle on both of my visits. It is a new mine and is in excellent condition as far as I was able to discover under the circumstances.

DIAMOND No. 3 MINE.

This mine was idle on my first visit. It is a new mine owned by the Diamond Coal Company, of Chicago, Ill., situated on the N. W. quarter of Sec. 7, T. 13, R. 7. No recommendations were found necessary on my second visit, as the mine was in good condition.

BRIAR HILL MINE.

Briar Block Coal Company, Clay City. On my first visit, April 4th, I found the whole air current being sent around all the workings. A large part of the air course was badly choked and the ventilation of the mine very bad, and I suggested that the air be split by opening a certain door in the mine so that about three-fourths of the air would be allowed to pass to working places without passing through the obstructed air course. On a visit made shortly afterward to see if this and other suggestions had been complied with, I found that it had not, and that pillars were being removed which would make it impossible, and the mine was in very little better condition than on my first visit. I opened the door myself and ordered the work stopped on the pillar. The desired effect was produced and I have heard no complaint of the air from there since. This is one of the few instances, since I took charge of the work, in which I have to complain of the refusal of mine officials to take my advice.

AMERICAN BEAUTY.

Owned by Zeller & Sigler Coal and Mining Company. Situated on Center Point Branch of the Vandalia Railroad, one mile east of Ashersville. On my first visit the mine was idle, but I found the air courses in bad condition. On the second visit the mine was in fair condition. It will probably be finished during the present season.

No. 6 MINE.

Brazil Block Coal Company, located on the Brazil Division of the C. & E. I. R. R., three miles north of Brazil. I found this mine idle on my first visit, May 10th, but in apparently good condition. Shortly after complaints reached me, and on a second visit I found that the working force had been greatly increased and there was not air enough for the men then in the mine. Several improvements were suggested which were carried out, and on a third visit I found the mine in good condition. No complaints have reached me from there since that time. Pillars are being drawn preparatory to abandoning this mine, and it will probably be finished during the present season.

EUREKA No. 1 MINE.

On my first visit I found this mine idle and in apparently good condition. On a subsequent visit I found a good deal of air escaping and smoke hanging in a number of places. The upper vein had also been opened and was not properly ventilated. I spent nearly two days with the mine boss on this visit and found that the mine was in such a condition that a large amount of time would be necessary to place it in proper condition for work. The mine boss knew what was necessary and how to do it.

EUREKA No. 2 MINE.

Just east of Carbon. When first inspected ventilation was very poor on account of the small space available for a down-cast; on my recommendation this was enlarged to double its size and partitions between the down-casts and up-casts were repaired. On my second visit I found the mine in good condition.

EXCELSIOR MINE.

Located northwest of Perth one mile. There are two veins worked in this shaft, and it is well ventilated in both. Some dangerous roof is found in the top vein, but with this exception the mine is in excellent condition. By a break in the roof this mine was flooded by water from the abandoned works in a vein overlying the two now being operated. Though all the men employed were at work at the time, and the water nearly reached the roof in places, by good management on the part of H B. Ehrlich, Superintendent, all were gotten out without injury. The water is being pumped out and the mine is nearly ready for operation again.

FORTNER MINE,

One mile southwest of Turner, is a bituminous mine. The vein is nearly seven feet high and lies very near the surface, in numerous places not over eight feet of strata overlying the coal. There are so many openings that a complete system of ventilation for the mine is impossible. However, on my visit to the mine on November 28 I found there was good air in all parts of it from natural ventilation, and the company have two fans on the premises ready to be put into immediate use if necessary. In other respects the mine is in excellent condition. It is owned by C. Ehrlich. Ell. Tibbits is the mine boss.

FAIRVIEW MINE.

Located four miles northwest of Brazil. At the time of my first visit this mine was idle, making some repairs in the bottom vein. As far as could be learned under the circumstances the mine was in good condition. On the two subsequent visits I found the mine idle, and did not make another inspection.

GART. No. 3.

Located two miles northwest of Harmony. Preparations had been made to abandon this mine, when it was determined to work another piece of coal by the same opening. On my first visit I found it very poorly ventilated, and suggested quite a number of improvements. These were made and the bottom vein workings were put in a fair condition. A tunnel was driven from the bottom to the top vein, and on my second visit I found the air very poor in that part of the mine, but preparations were being made which I thought would remedy that, and since the completion of the improvements I have heard no complaint.

GART. No. 4.

This mine was in good condition on my first inspection, all the work being done upon pillars, and since that time the mine has been worked out and abandoned.

GART. No. 5.

Located in the town of Cardonia. It is one of the largest mines in the State, employing about 350 men when running to its full capacity. This mine is well laid out, and the only objection I can find with the way it is conducted is that break-throughs are not closed up as quickly as they should be, which makes the air very poor near the faces of the entry. On my last visit I found less reason to complain of this, and the mine was in good shape in every way.

GLADSTONE MINE.

Located on the line between Clay and Vigo counties one-half mile north of the "Big Four" Railroad. Some trouble is experienced in this mine from fire damp, but the ventilation is kept in such condition that there has been no accident from this cause since January, when Joseph Debouille was severely burned.

HARRISON No. 2 MINE.

Located four miles north of Clay City. Was working only one side when inspected April 30th. It was in fair condition with respect to safety and ventilation. The second inspection of the mine was made by Mr. McCloud in July, who reported favorably of its condition.

GARTSIDE MINE.

Located one mile north of Knightsville. On my first visit April 30th I found that no work was being done in the mine, except in drawing pillars preparatory to abandonment, and the mine was in as good condition as possible for that work to be done. I am informed that the mine will be abandoned during January of this year.

LOUISE MINE.

This mine was visited twice during the year and found in fair condition on both occasions. It is worked on the single entry plan and the doors used in directing the ventilation are frequently allowed to stand open. I recommended that additional trappers be employed and the doors more carefully attended. When this is done the mine will be in good condition.

McINTOSH No. 2.

This is a new mine situated one mile east of Brazil. During the year an escape shaft has been sunk, covers and safety catches put upon the cages, and safety gates at the top of the shaft. On the occasion of my last visit, November 28th, the mine was in fair condition. Another split in the air current is necessary, which the superintendent promises to make soon.

NELLIE MINE.

Located one mile south east of Brazil. Was visited twice during the year. The first visit, April 25th, the east side was not being worked at all and there were but few men on the west. On account of water lying in the air course the current was very weak in places. I recommended that the water be taken out which had been done before my next visit, and conditions there materially improved, though nearly the same thing existed on the east side as were on the west at my first visit. By the opening of a new air course this trouble has been largely done away with and the mine is now in fair condition.

NICKLE PLATE MINE.

Located one mile south of Benwood. Several improvements in the way of stoppings and air courses have been made at this mine during the year and on my last visit I found it in fair condition with the exception of a few places in the top vein, which was just being started, it having been unworked for some time. I recommended that the air course leading to it be cleaned out and two breakthroughs made, which Mr. Cox, the mine boss, promised to have attended to immediately.

OTTER CREEK MINE.

This mine was not working the bottom vein at the time of either of my two visits, the workings in the top vein were in excellent condition.

PRATT MINE,

One mile west of Perth, was found in a satisfactory condition on each of my two visits, though the mine boss was pushing some further improvements in the way of shortening his air current to secure better results.

SUPERIOR MINE.

A new mine one-half mile west of Turner, in a seven foot vein of bituminous coal, began taking out coal in January 1895, during the year has sank an escape shaft, placed covers and safety catches on his cages and safety gates on the shaft. The shaft was sunk on a fault which threw the coal down about eighteen feet, consequently only one side of the mine is being worked. Owned and superintended by P. Ehrlich.

WORLD'S FAIR MINE,

One mile northeast of Brazil, was found in good condition on the occasion of both of my visits.

BRAZIL MINE.

Situated one mile north of the World's Fair mine. Works three veins, was idle during the greater part of the year. When examined October 27, shortly after having begun work, was found in fair condition. The strata between the top and the second vein are very weak and there are several falls through which the air escapes between the two veins. In spite of this the mine is well ventilated, and in a safe condition, with the exception of the middle vein where the roof will require to be constantly watched.

CRAWFORD No. 5 MINE.

This mine is worked out and abandoned, as is also No. 9 of the Brazil Block Coal Company. Brazil Block Coal Company's No. 10 mine was not in operation during the year until the latter part of November and I have not had an opportunity to visit it since operations were resumed.

OWEN COUNTY.

Lancaster Mine, No. 3, was finally abandoned during the summer of 1895, and No. 4 has been opened up and is in good condition for a new mine, though all the provisions of the law have not been complied with at the date of our last visit.

PARKE COUNTY.

COX No. 3 MINE.

Near Coxville, Indiana. This is a bituminous mine owned by the Brazil Block Coal Company. This mine has been idle a good deal during the year on account of differences between miners and operators. I did not have an opportunity to examine it while it was in operation. As far as I could discover from the examination when the men were not at work the mine is in fair condition as regards ventilation, but there is some very dangerous roof in the mine which requires constant watching. Some accidents happened in spite of the utmost care, used on part of the mine boss and the superintendent.

CRAWFORD No. 1 MINE.

Two miles northeast of Carbon. This mine was shut down during the greater part of the summer and after operations were resumed it worked so irregularly that I was not able to make a proper inspection of it during the year, but have been informed that the mine is in good condition.

LYFORD No. 1 MINE:

On my first visit to this mine I found that it was shut down for repairs and I could not get down. On my second visit I found the mine in a bad shape, but the owners were at work trying to improve the condition by cleaning out air courses, improving brattices and stoppings, and were building an over cast on the north side of the mine. These improvements will materially better the existing conditions. The slate overlying the coal is very hard to keep up with timbers and gives a great deal of extra work in mining the coal, besides the constant danger attending it, and great care is necessary to prevent accidents from that cause. The Lyford Mining Company has recently disposed of its holdings of coal property to the Calumet Coal Company, of Chicago, Ill., who are preparing to develop the same more fully than has heretofore been done, making the improvements noted above in No. 1 Mine, and are preparing to entirely remodel the No. 2 shaft, which has been idle for some years. This promises to be a more important point in coal mining than it has been heretofore.

MCINTOSH No. 1 MINE,

Owned by I. McIntosh & Co., was sunk to the bottom vein during the summer. A good quality of coal was found, of fair height and with a good top. The mine developed some fire damp, and one serious accident occurred during the year from an explosion of the same. Since that time the proper precautions have been taken to prevent explosions and no further damage has been done from that cause. The top vein workings of this mine are in a very dangerous and poorly ventilated condition and are being worked solely with a view to their further abandonment, which will probably be accomplished early in the present year.

MECCA Nos. 1 AND 2 MINES.

These mines are now owned and operated by the Otter Creek Coal Co., of Brazil, Ind. No. 1 was found in splendid condition when inspected on April 18th. No. 2 is being finished preparatory to abandonment.

PARKE No. 6 MINE.

This mine was visited several times, I having made two regular inspections and being called there twice on account of accidents resulting in death, which are noted in their proper place in this report. On my first visit I found insufficent air on the north entries on the east side of the shaft, and also on the fifth north on the west side. I suggested several improvements in air courses and doors and on my last visit found the conditions materially improved and the mine in good condition.

PARKE No. 8 MINE.

On my first visit to this mine I found it in fair condition, with the exception that breakthroughs were not closed properly as the workings advanced, which caused the air to be dull near the faces of the entries. On my second visit I found the air very bad in several of the entries on the north side of the mine, and suggested changes to be made which I thought would improve conditions there. On a third visit I found that they were working toward making the changes suggested and that in the meantime temporary measures have been taken to improve the faulty conditions, with fair success, and the mine was in a passable condition.

PARKE No. 9 MINE.

This mine was worked out and abandoned during the year.

SUPERIOR No. 1 MINE.

This mine has given me more trouble than any other during the year, and I have found it necessary to make four visits for the purpose of having my suggestions complied with, looking to the better ventilation of the mine. On my last visit, however, I found that the mine had been given a thorough overhauling and was in fair condition. Owing to the character of the roof of this mine it is very difficult to keep the air courses and entries open and in a safe condition, and it can only be done by constant watchfulness.

SUPERIOR No. 2 MINE.

Is a new mine sunk during the year and is only fairly opened up. It is located about half a mile southwest of No. 1 mine, and promises to be a good mine, as it is well laid out and the coal is proving of good quality. Ventilated by a twelve-foot fan, and is fully equipped with all appliances and safeguards required by law.

PARKE No. 7 MINE.

From a combination of causes I have been unable to inspect this mine during the year, but I have been reliably informed that preparations are being made to abandon it. For quite a good portion of the year it was not in operation, and when it was, other duties kept me so busy that I could not conveniently visit it, but hope to do so soon.

FOUNTAIN COUNTY.

SHIPMAN MINE.

This mine worked only a few months during the year and was finally transferred to the Indiana Bituminous Coal Company, during the month of November. I did not inspect it during the year, and have no record that my predecessor did. It was suspended at the time of both of my visits to Fountain County.

SILVERWOOD MINE.

This is a new mine situated about a mile and a half northwest of Silverwood, shaft sixty-five feet deep, into a good vein of bituminous coal. Though not fully equipped when I visited it, it was in a fair condition as to safety and ventilation.

STURM MINE.

Owned by M. Sturm, Silverwood, Ind. This is a small mine, employing from twelve to fifteen men. The underground pillars are being drawn and the mine will soon be abandoned. On my first visit I ordered safety gates put upon the top of the shaft, and suggested that the rope being used was too light for the work required of it. On my second visit, a month later, I found that gates had been erected as suggested, and was informed that a new rope had been ordered. This mine may be run on a small scale for some time before being entirely abandoned, as the underground workings are in good condition.

DAVIESS COUNTY.

BUCKEYE MINE.

Located near Cannelburgh. This mine has not been in operation for some time. At the time of my visit, they were making arrangements to take the water out preparatory to starting the mine.

MONTGOMERY No. 1 MINE.

Located at Montgomery, operated by the Daviess County Coal Co. The coal is three feet eight inches thick, worked by shaft. When inspected December 19, it was in bad condition. In some parts of the mine the ventilation was bad, due to badly closed breakthroughs. Several changes were ordered which the company agreed to do at once. They employ eighty-five men at this mine.

MONTGOMERY No. 2 MINE.

Located at Montgomery, operated by Daviess County Coal Co. The coal is three feet eight inches thick, operated by shaft. When last inspected was in good condition. This mine employs fifty miners.

MUTUAL MINE.

Located at Clark Station. Operated by shaft, one hundred feet deep. The coal is partly cannel and partly bituminous, the cannel being three feet and bituminous one and one-half feet thick. This plaee was inspected on December 18, and found in good condition.

No. 4 MINE.

Owned by Cable & Kaufman Co. Located two miles south of Washington. This mine has been idle for two months. When last inspected was in good condition.

No. 9 MINE.

Owned by Cable & Kaufman Co. Located two miles south-west of Washington. This mine was inspected on April 7. Ventilation was found very bad, due to damp coming from old workings. The same were ordered brattieed off from the new workings.

STOYS' MINE.

Located at Raglesville. Owned and operated by Abraham Stoy & Son. The mine is situated two miles from the E. & R. R. R. The coal is three feet thick and of excellent quality. It is operated by shaft fifty feet deep. They employ twenty-three miners at this mine.

WINKLEPLECK MINE.

Owned and operated by Jonas Winklepleck. Located near Raglesville, two miles from the E. & R. R. R. Operated by shaft fifty feet deep. The coal is three feet thick and of excellent quality. I inspected this mine December 3, and ordered several changes made to place the mine in compliance with the law. This mine employs twenty-four miners.

WILSON'S MINE.

Located near Washington, Indiana. Operated by Washington Coal Co. The coal is six feet thick, of a good quality. This mine is nearly worked out, and they are drawing the pillars on nearly all the entries. This place is operated by shaft sixty-four feet deep. When last inspected was in fair condition.

GREENE COUNTY.

FLUHART MINE.

Operated by Linton Coal and Mining Company. Located one and one-half miles southwest of Linton, and operated by shaft seventy-two feet deep. The coal is five feet thick, of good quality. This mine was inspected March 25, when the air courses were badly filled with slate and water. The necessary changes were ordered made to place the mine in compliance with the law.

ISLAND VALLEY MINE.

Located two miles southeast of Linton, on the I. & V. Railway. The coal is five feet thick, of excellent quality for steam and domestic use. Operated by shaft fifty-two feet deep. The output at this place is about three hundred tons daily. When last inspected the mine was in good condition. Fifty men are employed at this mine.

ISLAND No. 1 MINE.

Owned by Island Coal Company. Located one and one-half miles south of Linton. Operated by shaft sixty-six feet deep. This mine has lately been equipped as a machine mine, and they also have the latest improved machinery for hauling and screening the coal. The coal is five feet thick, of excellent quality for steam and domestic use. They employ one hundred men. When last inspected was in good condition.

ISLAND No. 2 MINE.

Located at Linton, owned by Island Coal Company, operated by shaft ninety-five feet deep. This is a machine mine, one of the largest in the

State. They run twenty-two Harrison machines. The capacity at this place is one thousand tons daily. The coal is five feet thick and of excellent quality. They have lately put in rope haulage. One hundred and twenty-five to fifty persons are employed. In good condition when inspected.

SUMMIT MINE.

Located one mile west of Linton, on the I. & V. Branch R. R., operated by shaft ninety-five feet deep. The coal is five and a half feet thick, of good quality. This mine was inspected December 1st, the ventilation was found bad, due to badly stopped break-throughs. The necessary repairs were ordered and on my return two weeks later I found the mine in good condition. This mine employs 150 men.

SOUTH LINTON MINE.

Located one mile south of Linton, on a branch of the I. & V. R. R., operated by the South Linton Coal Company. The coal is five feet thick, of good quality, operated by a shaft eighty-one feet deep. They have lately put down a manway. When last inspected this mine was in excellent condition. This place has a daily capacity of 400 tons.

TEMPLETON'S MINE.

Located three-fourths of a mile southwest of Linton. This mine is operated by shaft, the coal is five and a half feet thick and of excellent quality. At present they employ less than ten men, but are putting in machinery preparatory to opening a large mine.

KNOX COUNTY.

BICKNELL MINE.

Located at Bicknell, Ind. Operated by the Bicknell Coal Company. The coal is four feet three inches thick, and of good quality. It is worked by a shaft ninety-seven feet deep. They employ forty-five miners at this mine, and when last inspected it was found in good condition.

EDWARDSPORT MINE.

Operated by the Hoffman-Edwardsport Coal Company. This is a new mine, having been opened within the past year. The coal is four and one half feet thick and of good quality; operated by a slope. This place was inspected December 16th, and found in good condition. They employ twenty-seven miners.

PROSPECT HILL MINE.

Located at Vincennes, Ind. Owned by Frank Clark, operated by a shaft 335 feet deep. The coal is three feet thick, of fair quality. It is underlaid with fire-clay of a very soft nature which heaves so that it is hard to keep roadways and air courses open, making it a very expensive coal to work. I inspected this mine on December 17th, and found the general condition of the mine bad.

PIKE COUNTY.

AYRSHIRE MINE.

Operated by David Ingle, Oakland City. This mine is located at Ayrshire, six miles east of Oakland, it is operated by a shaft twenty feet deep. The coal is five feet thick and of excellent quality. They employ about 150 miners. When last inspected the mine was in fair condition, except ventilation, which was bad, due to badly stopped break-throughs and use of curtains instead of doors. I recommended putting in doors and fixing up the break-throughs, which they readily agreed to do. I think the next inspection will find the mine in good condition.

BLACKBURN MINE.

Owned and operated by S. W. Little. Located at Blackburn Station and operated by a slope. The coal is seven feet thick with considerable sulphur. The company has lately put in the latest improved machinery for handling and screening the coal. They employ twenty-seven miners. When last inspected the mine was in fair condition.

HARTWELL MINE.

Owned and operated by Cable & Kaufman, Washington, Ind. Managed by Thomas Small. This mine is located near Augusta, on a branch of the Air Line R. R. It was inspected on Dec. 21st, and found in excellent condition. The coal is four feet thick. When the mine was inspected they were working sixty-nine miners and two mules in the mine, and five men on the outside.

LITTLE'S MINE.

Owned and operated by S. W. Little Co., Evansville, Indiana. Located at Little Star, on the Evansville & Indianapolis R. R. The coal is six and a half feet thick, of fair quality, operated by a shaft eighty-six feet deep. They employ sixty-five miners. I inspected this mine December 23d, and found it it good condition.

VERMILLION COUNTY.

FERN HILL MINE.

Located near Clinton. Was idle on my first visit. On my second visit, Aug. 19th, the mine was in good condition in all respects.

INDIANA BITUMINOUS No. 1 MINE.

Northwest of Clinton. This mine has been remodeled during the year and fitted with patent self-dumping cages, new boilers and a twelve foot fan, also a new eighty thousand pounds capacity track scales. These repairs were under way on my first visit and I did not inspect the mine. When inspected, Aug. 19th, the mine was in good condition.

TOREY No. 4 MINE.

On my first visit this mine was being sunk to the bottom vein, and no work was being done in the upper vein. On my second visit the mine was just starting, after a strike, and was in bad shape in the upper vein works. Very little work has been done in opening the bottom vein which is the same coal that is being mined at Lyford, in Parke County. This mine is located at Geneva, Vermillion County.

HAZEL CREEK No. 1 MINE.

This mine is being worked by a company of miners who have it leased from the Hazel Creek Coal Co. When examined it was in fair condition with the exception of one part of the mine where about eight men were at work. The air was very bad there, and I gave the mine boss ten days to remedy it or cease work there. I have since learned that that part of the mine was abandoned. There is nothing but pillar work left in the mine, but it may be run on a small scale during the whole of the present year.

VIGO COUNTY.

GRANT MINE.

Located near the town of Grant, on the C. & E. I. R. R. When examined this mine needed a good deal of improvement, as the road to the escape shaft had been allowed to fall in and the shaft was not available to the use of the men. The air in some parts of the mine was also bad, and I instructed the Superintendent to make the necessary improvements. He has since reported that this has been done, though I have not made a second inspection of the mine.

VIGO MINE.

One mile west of Foleyville. Is a new mine operated by slope. It is in good condition in all respects, well aired and safe. A safety spring was recommended on the top of the slope to prevent cars running back. On my second visit I found that one had been placed there.

RAY MINE.

At Seeleyville, Ind. Is a new mine opened by shaft. Is fitted with self-dumping cages, and is aired by a twelve-foot fan. An escape shaft is being sunk at this mine, and is nearly completed at this writing. When this is done the mine will be in excellent condition in all respeets.

VICTOR MINE,

Southeast of Fontanet, was found in good condition, except that the roof is dangerous. However, it was well timbered and all possible care taken to prevent accidents. This mine is nearly worked out, and will probably be abandoned during the year.

UNION MINE.

North of Fontanet, is a new shaft, fitted with self-dumping cages. I found all the conditions of the law complied with at this mine. The roof is very bad in some places, but proper care has been taken to prevent accidents, and none were reported from this cause during the year.

STAR MINE.

Just south of Fontanet. I found this mine in excellent condition, in all respects. They are now engaged in drawing pillars preparatory to abandoning the mine and it will probably be completed during 1896.

PEERLESS MINE.

Located one-half mile north of the Coal Bluff crossing, on the C. & E. I. R. R. This mine has run so irregularly during the year, that I have been unable to visit it when it was at work. When inspected it was in fair condition and I considered no recommendations necessary.

NICKLE PLATE MINE.

Located one mile southwest of the Vigo mine. The coal lies nearly on a level with the valley and is brought to daylight by mules The mine is aired by two fans, and was in good condition when inspected, except that breakthroughs were not being well closed, however there was plenty of air in the mine to keep it well ventilated, in spite of the waste.

HERCULES MINE.

This mine was worked out and abandoned during the year.

DIAMOND MINE No. 1.

This mine did not resume operation after the stoppage on May 1st. It has been definitely abandoned. The machinery has been moved to Diamond No. 2 near Grant, which has been opened since that time.

EAGLE MINE.

Located just west of the Vigo mine. Opened by a slope. When first examined this mine was in a very bad condition for air, but on my recommendation a fan was erected and on subsequent examination the mine was found in good condition.

SULLIVAN COUNTY.

SHELBURN MINE.

Located in the town of Shelburn. This mine was examined by Mr. McCloud who reports it in bad condition, dirt being allowed to accumulate in the air courses, and the road to the escape shaft being badly filled up. It has recently passed into the hands of C. C. Heisen, Chicago, who has made a great many improvements on the outside of the mine during the year, and I hope that the inside condition will be bettered soon.

OLD PITTSBURGH MINE.

Located at Hymera. Was in fair condition when examined, except that the roof was bad in places, and the air having to travel through old works, was not as good as it should have been. Electric machines are used in this mine, and the coal is brought to the bottom of the shaft by two electric motors. There has been several changes in superintendents during the year so that it has been impossible to have improvements made systematically, and on a later visit, the air courses were found in very bad condition.

JUMBO MINE,

Located at Jackson Hill, is in fair condition only. The mine has been opened up extensively and proper attention has not been given to the air courses, so that the air is bad in some parts of the mine. I have recommended that the air be split on each side of the shaft, and the superintendent has promised to comply with this.

STAR MINE.

Located at Grammercy Park. This mine was found in fair condition on all visits made during the year, as it is nearly new, with good roof and bottom. Mr. McCloud resigned the position of Assistant State Mine Inspector to take charge of this mine, and reports from there lately indicate that conditions have considerably improved.

CURRYSVILLE MINE.

One mile north of Shelburn on the E. & T. H. R. R. Is in poor condition; the main shaft in several places has given way and it needs a recurbing. The air is very poor at the head of the workings.

PHOENIX MINE.

Located at Alum Cave, on the line between Clay and Sullivan counties. Some repairs were needed here on the first visit. On the second visit the mine was found in fair condition, while there is still room for improvement.

BUSH CREEK MINE.

Located four miles east of Sullivan on I. & St. L. R. R. Owned by Watson, Little Coal Co. Operated by shaft one hundred and six feet deep. This is a new mine, having been opened within the last two years. The coal is five feet three inches thick, of good quality. When last inspected the mine was in good condition. They employ thirty-three men.

HANCOCK MINE.

Located at Farnsworth on I. & St. L. R. R. Owned by Hancock & Conklin. Operated by shaft seventy-three feet deep. When last inspected this mine was in excellent condition. The coal is four and a half feet thick, of good quality. They employ forty men in the mine.

LYONTON MINE.

Owned by Lyonton Coal Co. Operated by shaft forty-five feet deep. The coal is five feet in thickness of good quality. This mine has been idle for several months.

DUGGER MINE.

Located at Dugger on the I. & S. R. R. and I. & V. Coal Branch. When first visited, Mr. McCloud reported the mine in a bad shape. The mine changed hands during the summer and is now being operated by the Indiana & Chicago Coal Co. After taking possession of the mine they spent nearly three months in making repairs underground, and when last visited it was found to be in a fair condition.

DUGGER CÖOPERATIVE MINE.

Located one mile west of Dugger. Is operated on a small scale by a joint stock company. Mr. McCloud, on his first visit, ordered that an escape way be provided at this mine. Some work was done towards this but on our last visit nothing was being done toward completing it. We found that less than ten men were being employed under ground and that, consequently, the law did not compel the company to make the opening. The ventilation was fair and the condition of the mine in other respects good.

Several mines reported from Sullivan county last year by my predecessor are now employing less than ten men and have not been inspected nor required to report to this office since my term began. Myself and assistants found our time so fully employed in inspecting and recommending improvements in the larger mines of the State and seeing that our recommendations were complied with there that we were compelled to entirely neglect those to which the law does not apply, and may have omitted some mines employing between ten and fifteen men. However, during the present year we shall attempt to visit, at least once, all mines in the State, and be able to report fully on their condition, production and the number of men employed in them. In another part of this report I give an estimate of the amount of coal produced by mines of this class, based on the best data I have been able to obtain in the time at my disposal, which shows this to be a very important industry in itself.

VANDERBURGH COUNTY.

DIAMOND MINE.

Was inspected twice and found in fair condition on both occasions. In common with all mines in Vanderburgh County this mine has a good roof and the ground is dry. During the summer the outside work of the shaft has all been rebuilt and made new and the mine is in good condition.

FIRST AVENUE MINE.

This mine was visited twice during the year, and on my second visit I found that several improvements had been made during the year, by cleaning out the air course, bratticing break-throughs, and hanging new doors in the mine, putting it in a fair condition.

SUNNYSIDE MINE.

Was visited twice during the year. Between my two visits the main air course had been cleaned out and three patent doors hung, which, with other needed improvements, has brought the air to a good condition. In other respects the mine is all that is to be desired.

UNION MINE.

This mine is operated by the Evansville Union Coal Mining Company, which is composed entirely of persons working in and about the mines. The mine was found in bad condition on my first visit, it having very poor arrangements for ventilation and no escape shaft. Curtains were used in place of trap doors and the signal law of the State was not being complied with. I recommended the necessary change and that an escape shaft be sunk immediately. This was started and sunk about 100 feet, and on my second visit work in it had been abandoned for some time. I ordered that all men except ten be taken out of the mine unless work was immediately resumed on the escape shaft. After trying this for some days they decided to push the work on the escape shaft and are doing so at the end of the year.

INGLESIDE MINE.

Operated by John Ingle & Co. This is the oldest mine in the State. The main entry being driven a mile from the bottom of the shaft, an endless rope is used for drawing coal in the main entry, a distance of 1,300 yards. The mine was found in good condition on both of my visits, except that the air courses required cleaning in some places. On my second visit I found that this had been done and the mine was in good condition in all respects.

PERRY COUNTY.

CANNELTON MINE

Located three miles northeast of the city of Cannelton. Is operated by a drift. This mine was found in good condition when inspected in April. It was idle during the latter part of the year and was not visited again. Work was resumed on December 10.

TROY MINE.

Is located at Troy on the Ohio River. Is ventilated by a furnace, which at times is not properly cared for, causing the air to be bad in the mine. If it should be attended to sufficient air would be provided, and the mine would be in good condition. This mine was visited but once during the year, as it was idle during a great part of the summer.

WARRICK COUNTY.

STAR MINE.

Located at Newburgh. Was inspected twice and found in good condition on both occasions.

LAUDER MINE.

Located at Boonville. Mine machines are used in this mine, it is well ventilated, has a good roof and is in good condition in all respects.

HOWARD JENNINGS MINE.

This is a new mine located near Chandlers on the L., E. & St. L. R. R. When visited on September 9, it was not fully equipped but the persons in charge promised to comply with the law in all respects, as soon as possible. Some fire damp has been found in this mine.

LIST OF ACCIDENTS—FATAL.

January 11, 1895. Diamond mine, Diamond Block Coal Co. Walter Hays, fall of rock; killed.

January 12, 1895 Gart. No. 3 mine, B. B. C. Co. J. W. Elliott, fall of rock in room; died same evening.

January 16, 1895. Gart. No. 4 mine, Clay county. George Smallcombe, killed by falling slate.

January 25, 1895. Prospect Hill mine, Knox county. J. Todd, killed by falling down shaft.

February 2, 1895. Ingleside mine, Vanderburgh county. Robt. Love, injured by premature blast; died a week later. No report made to this office until in April.

March 14, 1895. Star mine, Warrick county. Patrick McGuire, killed by premature blast.

March 25, 1895. Parke No 6 mine, Parke county. Otis Jackson, killed by fall of slate.

March 26, 1895. Peerless mine, Vigo county. Richard Richards, caught by cage; died from injury.

May 21, 1895. Excelsior mine, Clay county. Dominie Gelwey, ignited keg of powder in his room and died next day.

June 17, 1895. Jackson Hill mine, Sullivan county. Michael Crynes and James Sity, killed by falling slate in working place.

August 12, 1895. Harrison mine, Clay county. Josiah Wells, killed by falling slate in entry.

September 17, 1895. Island No. 1 mine, Greene county. Patrick Dugan, killed by mine cars.

October 7, 1895. Brazil mine, Clay county. Joseph Brown, killed; caught by ascending cage.

October 28, 1895. Prospect Hill mine, Knox county. Bernard Clements, killed by falling slate while timbering.

December 10, 1895. Cox No. 3 mine, Parke county. John Hokin, killed by a fall of slate in a room.

December 10, 1895. Cox No. 3 mine, Parke county. J. Davie, hurt by same fall; died two days later.

December 10, 1895. Parke No. 6 mine, Parke county. Ed. Opendorf, killed; fell in front of loaded trip.

December 17, 1895. Union mine, Vanderburgh county. Carl Muller, injured in air shaft; died two days later; supposed to have fallen in a fit.

December —, 1895. Vigo mine, Vigo county. Marion Hayne, killed by a loaded mine car.

I have learned of three deaths by accident in the small mines in the State during the year, but have been unable to learn the names of the injured parties or the dates of the accidents.

After writing the above I learned that one of the parties killed in small mines was Ernest Lester, at Carlisle shaft, by pushing a car into the shaft, December 23, 1895.

LIST OF ACCIDENTS—SERIOUS.

January 2, 1895. Gough mine, Warrick county. Jos. Cullen, hip dislocated.

January 11, 1895. Diamond mine, Diamond Block Coal Company. Michael McGragian, fall of rock; leg broken.

January 14, 1895. Gladstone mine, Clay county. Jos. Deboulle, badly burned by explosion of fire damp.

February 19, 1895. Hancock & Conklin mine, Sullivan county. R. C. Carty; draw slate fell, not timbered; leg broken.

February 22, 1895. Gart. No. 1 mine, B. B. C. Co. Sam. Batchelor, pushed block from in front of empty car, which ran against him; leg broken.

March 12, 1895. Gart. No. 3 mine, Clay county. John Sims, fall of slate; injured in the back.

March 14, 1895. Superior mine, Clay county. Wm. Cushner, lost a finger.

March 25, 1895. Parke No. 6 mine, Parke county. Thos. Gibson, by fall of slate; arm broken, back sprained.

March 29, 1895. Nickel Plate mine, Vigo county. James Feathers, fall of coal, mining off shot; leg broken.

March 30, 1895. Diamond mine, Clay county. Corsetto Farnio, fell in a fit; broke his nose.

May 24, 1895. Gart No. 4 mine, Clay county. Andrew Hamilton, fall of coal; leg broken.

May —, 1895. Buckeye mine, Greene county. T. G. Morgan, fall of slate; foot injured.

May 28, 1895. Phoenix mine, Sullivan county. E. H. Bisby, falling from elevator frame; arm broken.

May —, 1895. Grant mine, Vigo county. Joe Neace, by falling slate; leg broken.

June 22, 1895. Pratt mine, Clay county. Levi Evans, fell down drop shaft; ankle and hip broken.

June 29, 1895 Harrison No. 2 mine, Clay county. George Everet, fall of slate in room; back injured.

July 1, 1895. Phoenix No. 2 mine, Sullivan county. George Miller, fall of coal; back fractured.

July 11, 1895. Ray mine, Vigo county. Two men hurt, one by falling slate, one by shot through pillar.

July 8, 1895. Fairview mine, Clay county. John Baird, by falling slate; leg broken.

July 18, 1895. Gart No. 3 mine, Clay county. Willis Hice, hand crushed by falling coal.

July 30, 1895. Lyford No. 1 mine, Parke county. Joe Caravelle, fall of slate; leg broken.

August 13, 1895. Nellie mine, Clay county. Ire Hadley, by falling slate; arm broken.

August 19, 1895. No. 4 mine, Daviess county. George Sutherland, hurt in the back by draw slate.

August 19, 1895. No. 3 Gart mine, Clay county. Dan. Mooney, finger taken off by mine car.

September –, 1895. Nickel Plate mine, Vigo county. A. J. King, falling slate; injury not stated.

September –, 1895. Curryville mine, Sullivan county. A. N. Colohean, injured in the back by falling slate.

September 9, 1895 Briar Hill mine, Clay county. Chas. Miller, leg bruised by mine car.

October 2, 1895. Island No. 2 mine, Greene county. Ed. Sherwood and Al. Greenwood, injured by falling coal.

October 9, 1895. Pratt mine, Clay county. Edward David, fall of coal; leg broken in two places.

October 9, 1895. Hazel Creek No. 2 mine, Vermillion county. John Kemp, hurt by premature blast.

October 9, 1895. Hazel Creek No. 2, Vermillion county. John Crumby, arm broken.

October 9, 1895. McIntosh No. 1, Parke county. Wm. James, seriously burned by explosion of gas.

November 11, 1895. Silverwood No. 2, Fountain county. Elsnor Vickrey, fell off cage; leg broken.

November 28, 1895. B. B. C. Co., No. 8 Mine, Clay county. George Crynock, falling slate while mining; collar bone broken.

November 13, 1895. McIntosh No. 1 mine, Parke county. Henry Prulheire, leg mashed between mine cars.

November —, 1895. Brazil mine, Clay county. Adam Metz, foot mashed by falling stone on entry.

November —, 1895. Brazil mine, Clay county. Lue Haliger, hand mashed by falling coal.

December 30, 1895. Island No. 2 mine, Greene county. Wesley Brooks, leg broken by a shot.

December 3, 1895. Cox No. 3 mine, Parke county. James Yadau, fall of slate in room; thigh broken.

December 12, 1895. Brazil Block No. 8 mine, Clay county. Charles Sims, head bruised by falling slate while loading coal.

December 23, 1895. Pratt mine, Clay county. John Farley, hurt by fall of slate.

December 23. 1895. Pratt mine, Clay county. Charles Riggs, hurt by mine car; also a mule killed.

December 2, 1895. Brazil Block No. 1 mine, Clay county. Ed. Murray, lost a finger by mine car jumping track.

December 17, 1895. Gart. No. 3 mine, Clay county. David Waugh, badly strained by ascending cage; head caught on bunting.

December —, 1895. Gart. No. 5 mine, Clay county. Charles Simons, leg broken by mine car.

December 10, 1895. Bicknell mine, Knox county. Ade Vincent, seriously hurt by falling coal.

December 18, 1895. Crawford No. 1 mine, Parke county. William Moore, leg broken by falling slate and timbers.

December —, 1895. Jumbo mine, Sullivan county. John Pope, hand mashed by railroad cars.

December —, 1895. Ingleside mine, Vanderburgh county. A miner, name not given, arm broken by a shot in coal.

December 16, 1895. Union mine, Vigo county. Ed. Skoworgo, driver, crushed by mine cars.

LIST OF ACCIDENTS—MINOR.

February 18, 1895. Parke No. 10 mine, Parke county. Thos. Bingham and Alf Watkins injured on cage; engine got away from engineer. Bingham bruised about head, arm and leg; Watkins ankle joint hurt.

February 22, 1895. World's Fair mine, Clay county. Joseph Beadlin, leg hurt by falling slate.

March 11, 1895. Dugger mine, Sullivan county. George Schofield, hurt slightly, falling slate.

April 23, 1895. Vigo mine, Vigo county. D. Hornady, foot crushed by coal falling off cars.

May 23, 1895. No. 1 mine, B. B. C. Co., Clay county. Neal Watts, coal fell, hand injured; off two weeks.

May 23, 1895. Same place. Fred. Phelps, draw slate fell.

March 29, 1895. Vigo mine, Vigo county. Steve Lovas and George Spoors burned by explosion of powder, making cartridges.

June, 1895. No. 1 mine, B. B. C. Co., Clay county. Michael Rau, foot hurt, fall of coal; off ten days.

June 17, 1895. Phenix mine, Sullivan county. James Lindsey, leg bruised by mine car jumping track.

June 17, 1895. Victor mine, Vigo county. Jeff. King, hurt by mine cars.

June 18, 1895. No. 4 mine, Daviess county. George Wetzel, back hurt.

June 24, 1895. Summit mine, Greene county. Nathan Holman, fall of slate in room, hip hurt.

June 24, 1895. Same place. George Wise, hurt by falling coal.

July 24, 1895. No. 8 mine, Clay county. Harmon Wax, leg bruised, falling slate in room.

July 24, 1895. Same place. Thos. Trump, foot crushed, falling coal.

July 26, 1895. Harrison mine, Clay county. George Ramsdell, slightly hurt by falling slate.

July 26, 1895. Nickel Plate mine, Clay county. Henry Atkins, shot; not serious.

August —, 1895. Crawford No. 1 mine, Parke county. Wm. Bucholtz, foot hurt by mine car.

August —, 1895. Nickel Plate mine, Clay county. Michael Navin, hurt by falling slate.

August 15, 1895. Same place, James Stott, hand mashed by falling slate.

August 15, 1895. Same place, A. Nicodemus, hurt by falling slate.

August 15, 1895. Excelsior mine, Clay county. W. C. Conner, bruised by falling slate.

August 19, 1895. No. 6 mine, B. B. C. Co., Clay county. Wm. Andrews, hurt by falling slate.

September 6, 1895. Star Mine, Sullivan county. Jos. Krakowsky, mashed two fingers; how not stated.

September 13, 1895. Lauder Wooley mine, Warrick county. A. H. Cochran, back injured by falling slate.

September 24, 1895. Pratt mine, Clay county. John Jones, fall of slate; knee hurt.

September —, 1895. B. B. C. Co. No. 1 mine. Sam Genet, foot hurt by draw slate.

September 24, 1895. Gart No. 3 mine, Clay county. Robert Pimerman, lost two fingers by railroad cars.

October 11, 1895. Victor mine, Vigo county. David Gwinn, ankle bruised while handling slate.

October 21, 1895. Dugger mine, Sullivan county. Wm. Headley, slightly hurt by mine cars.

October —, 1895. Parke No. 6 mine, Parke county. Wm. T. Carroll, back hurt by falling slate.

October 24, 1895. B. B. C. Co., No. 8 mine, Clay county. Hugh Haggerty, fingers mashed, railroad cars.

October 26, 1895. Summit mine, Greene county. Tim Pool, ankle bruised by mine cars.

October 24, 1896. Nickel Plate mine, Vigo county. Robert Cuthbertson and Wm. Cuthbertson, slightly injured by draw slate.

November 2, 1895. Phenix mine, Sullivan county. Tom Griffith, head cut by falling coal.

November 8, 1895. Same place. Lloyd Nugers, hip bruised by mine car.

November 9, 1895. B. B. C. Co., No. 1 mine, Clay county. James Shields, leg injured; fall of slate in room.

November 11, 1895. Same place, Wm. Patrick, arm injured by mining machine.

November 14, 1895 Keen Davis, hand bruised while handling coal.

November 16, 1895. M. Stoupo, hand bruised by revolving screen.

November 20, 1895. Parke No. 8 mine, Parke county. Fred Wimmer, foot mashed by falling coal.

November 23, 1895. Union mine, Vanderburgh county. Theodore Perasat, foot mashed between mine cars.

November 27, 1895. Crawford No. 1 mine, Parke county. William Bucholtz, Sr. Knee hurt by falling coal.

November 28, 1895. Gart. No. 3 mine, Clay county, Wm. Travis, finger broken.

December 3, 1895. Cox No. 3 mine, Parke county. West Carroll, leg hurt by falling coal.

December 3, 1895. Nickel Plate mine, Clay County. James Phillips, slightly injured by falling coal.

December 4, 1895. Same place. Charles Morman, finger mashed; how not stated.

December —, 1895. Brazil mine, Clay county. Bert McAllister and John McGuire each had a hand mashed with falling coal.

December 17, 1895. Nellie mine, Clay county. Wm. Ball, leg hurt by falling coal.

December 23. Briar Hill mine, Clay county. James Blakely, slightly hurt by falling coal.

December 18. Island No. 1 mine, Greene county. Dora Benjiman, wrist hurt by mine car.

December 3. Summit mine, Greene county. Nick Woods, hurt by falling coal.

December 19. Summit mine, Greene county. Wm. Brown, caught by a mine car.

December 3. Dugger mine, Sullivan county. Jasper A. Cumbaugh and W. U. Somers, hurt by delayed shot.

December 20. Parke No. 8 mine, Parke county. Frank O'Donnel, back bruised by falling slate.

December 11. Phenix mine, Sullivan county. James Anderson, ankle sprained by a mine car.

December 17. Phenix mine, Sullivan county. Joe Drake, ankle sprained by a car.

December 17. Phenix mine, Sullivan county. James Wilson, finger mashed on right hand by a car.

Table showing the causes of accidents occurring during the year

CAUSE.	Fatal.	Serious.	Minor.	Total.
Fall of roof	12	21	20	53
Fall of coal	....	9	14	23
By mine cars	3	8	13	24
By explosion of gas	....	2	....	2
By explosion of blasts	2	4	3	9
By cages in shaft	2	2	2	6
By railroad cars	....	1	2	3
Miscellaneous	1	5	8	14
Fell down shaft	3	1	....	4
Totals	23	53	62	138

Table showing the number of accidents in each county during the year.

COUNTY.	Fatal.	Serious.	Minor.	Total.
Clay	6	24	28	58
Daviess	....	1	1	2
Fountain	....	1	....	1
Greene	1	5	6	11
Knox	2	1	....	3
Owen	....	....	....	....
Parke	4	6	8	18
Perry	....	....	....	....
Pike	1	....	....	1
Sullivan	3	5	11	19
Vanderburgh	2	1	1	4
Vermillion	....	2	....	2
Vigo	2	6	6	14
Warrick	2	1	1	4
Totals	23	53	62	138

It will be seen from the above table that falls of roof and coal are responsible for more than half the accidents happening in the State. In a large majority of cases accidents from these causes are to be attributed to the carlessness either of the person injured or that of the person whose duty it is to see that travelling ways in the mines are made safe.

There are some exceptions to this rule, as an examination will not always discover defects in the roof of the mine, however carefully it may be made. Still it can not be too strongly urged upon those charged with the duty of making this examination, and the persons who are to incur the danger, that a frequent and careful examination of the roof and coal in the travelling ways and at the working places is absolutely necessary to render the work of the mine employe even comparatively safe. The three fatal injuries resulting from mine cars during the year were of such a character that the persons injured were largely responsible for the accidents. Two of them were of drivers who were riding upon the front end of the cars, so that they could be near their mules, which is a very common practice in the mines, though the law expressly forbids any person from riding upon a loaded car. This is treated as implying an exception in the case of drivers and persons in charge of cars where haulage systems are employed, and indeed it appears that this exception is necessary. The most that the Inspector can do in such cases is to recommend that extraordinary care be taken to prevent accidents, by the persons whose duty requires them to occupy such places.

Of the accidents noted as having been caused by the explosion of blasts, all but two were caused by persons becoming impatient of waiting for their shots to explode after having been lighted, and in returning to see what was wrong the explosion took place while they were in range of coal thrown from the shot. These could have been prevented by allowing the proper time to elapse before returning to see whether the fuse had died out. Of the two exceptions, one was caused by a shot blowing through a pillar and the other occurred while a missed shot was being drilled out. Accidents of the first kind can be prevented by pillars being left at proper thickness, as would be done if the mine was properly surveyed, and their occurrence is the fault of the persons in charge of the mine. Death from falling down the shaft might have been prevented by compliance with the law requiring safety-gates to be placed upon the top of the shaft. One of them occurred at a mine where less than ten men were employed, and to which the Mining Law does not apply, and the others were caused by gates being left open. I found a great deal of reason to complain of this when I first began my inspection, but during the last few months of the year I inspected but one mine where the gates are not kept closed, except when in actual use.

REPORT OF STATE SUPERVISOR OF OILS.

PROF. W. S. BLATCHLEY,
State Geologist of Indiana.

SIR—In accordance with the statutes providing for the appointment of a State Supervisor of Oil Inspection and Deputy Supervisors of Mineral Oils and other substances, and to regulate the sale of the same for illuminating purposes, I herewith submit my fourth annual report for the inspection of illuminating oils for the period commencing November 1, 1893, and up to and including October 31, 1894.

NELSON J. HYDE.
State Supervisor of Oil Inspection.

TABLE SHOWING PLACE OF MANUFACTURE.

Lima, Ohio	136,771
Cleveland, Ohio	10,729
Toledo, Ohio	4,148
Findlay, Ohio	845
Cincinnati, Ohio	732
Whiting, Ind	66,880
Oil City, Pa	13,221
Pittsburgh, Pa	3,963
Reno, Pa	1,737
Titusville, Pa	2,604
Franklin, Pa	1,730
Bear Creek, Pa	1,260
Washington, Pa	676
Freedom, Pa	354
Warren, Pa	122
Parkersburg, W. Va	632
St. Louis, Mo	40
Total	246,444

TABLE SHOWING STATES WHERE OIL WAS MANUFACTURED.

Ohio	153,225
Indiana	66,880
Pennsylvania	25,667
West Virginia	632
Wisconsin	40
Total	246,444

TABLE SHOWING INSPECTIONS BY STATIONS.

STATIONS.	Approved.	Rejected.	Total.
Evansville	18,100	132	18,232
Vincennes	8,712	....	8,712
New Albany	3,267	....	3,267
Jeffersonville	1,725	....	1,725
Madison	3,420	....	3,420
Brookville	1,450	....	1,450
Aurora	2,370	....	2,370
Greensburgh	644	....	644
Shelbyville	549	....	549
Columbus	2,040	....	2,040
Rushville	427	....	427
Union City	2,106	....	2,106
Richmond	6,210	....	6,210
Muncie	2,940	....	2,940
Indianapolis	59,406	252	59,658
Terre Haute	11,326	....	11,326
Crawfordsville	4,258	....	4,258
Brazil	1,140	....	1,140
Lafayette	12,143	....	12,143
Kokomo	2,185	....	2,185
Logansport	9,329	....	9,329
Delphi	1,495	....	1,495
Rochester	979	....	979
Whiting	4,768	....	4,768
Hammond	4,629	....	4,629
Valparaiso	1,475	....	1,475
Peru	5,943	....	5,943
Marion	2,986	....	2,986
Huntington	2,671	....	2,671
Ft. Wayne	13,854	....	13,854
South Bend	7,148	....	7,148
Elkhart	7,369	....	7,369
Goshen	2,629	....	2,629
Laporte	2,249	....	2,249
Michigan City	2,156	....	2,156
Warsaw	155	....	155
Louisville	7,031	....	7,031
Cincinnati	6,004	....	6,004
Toledo	664	....	664
Lima	11,441	....	11,441
Mansfield	2,923	....	2,923
Cleveland	3,744	....	3,744
Total	24 ,060	384	246,444

The following is a complete report of inspections from November 1, 1894, up to and including February 28, 1895, the end of my official term:

Number barrels approved	122,003	
Number barrels rejected	362	
Total		122,365

INSPECTION BY MONTHS.

	Approved.	*Rejected.*	*Total.*
November	30,686	......	30,686
December	35,513	132	35,645
January	31,567	230	31,797
February	24,699	......	24,699
Total	121,003	362	122,365

THE FOLLOWING TABLE SHOWS PLACE OF MANUFACTURE.

	Barrels.
Whiting, Ind	34,200
Lima, Ohio	64,881
Cleveland, Ohio	6,863
Toledo, Ohio	2,898
Findlay, Ohio	603
Oil City, Pa	6,165
Pittsburgh, Pa	1,572
Franklin, Pa	950
Reno, Pa	1,340
Washington, Pa	952
Titusville, Pa	809
Warren, Pa	457
Bear Creek, Pa	60
Rossville, Pa	25
St. Louis, Mo	90
Parkersburg, W. Va	500
Total	122,365

INSPECTION BY STATIONS.

Evansville	8,789	Delphi	690
Vincennes	4,186	Rochester	504
New Albany	1,426	Whiting	3,190
Jeffersonville	700	Hammond	2,303
Louisville	2,747	Valparaiso	838
Madison	1,689	Peru	2,854
Aurora	1,134	Marion	1,809
Brookville	690	Huntington	1,377
Greensburg	495	Fort Wayne	5,447
Shelbyville	720	South Bend	3,431
Columbus	1,368	Warsaw	662
Danville	396	Laporte	916
Rushville	576	Elkhart	3,560
Union City	1,245	Goshen	1,299
Muncie	1,010	Michigan City	1,047
Richmond	2,880	Cincinnati, Ohio	2,025
Indianapolis	27,827	Mansfield, Ohio	707
Crawfordsville	2, 05	Cleveland, Ohio	2,394
Brazil	80	Lima, Ohio	7,014
Terre Haute	5,670	Toledo, Ohio	775
Lafayette	7,300		
Kokomo	1,150	Total	122,365
Logansport	4,240		

Respectfully submitted,

NELSON J. HYDE,
State Supervisor of Oils.

REPORT OF STATE SUPERVISOR OF OILS.

OFFICE OF STATE SUPERVISOR OF OIL INSPECTION,
ROOM 92, STATE HOUSE,
INDIANAPOLIS, IND., January 13, 1896.

PROF. W. S. BLATCHLEY,
State Geologist of Indiana:

SIR—In compliance with an act passed February 25, 1891, I herewith submit to you my first report as State Supervisor of Oil Inspection. The report embraces the period between March first (1st), 1895, the beginning of my official term, and December thirty-first (31st), 1895, inclusive.

Respectfully,

C. F. HALL.

REPORT OF STATE SUPERVISOR OF OILS.

Having been appointed to the office of State Supervisor of Oil Inspection on March 1, 1895, I assumed the duties, after complying with the requirements of the law, and soon thereafter the following deputies were appointed as my assistants in the various parts of the State:

Viele, Walter	Evansville.	Magee, Wm. H	Lafayette.
Weems, Robert F	Vincennes.	Davidson, James G	Whiting.
Dorsey, C. B	New Albany.	Johnston, John M	Logansport.
Bowman, M. J	Madison.	Daly, W. F	Peru.
Mills, L. B	New Maysville.	Sebring, W. D	Portland.
Shirk, B. F	Muncie.	Thorward, Theo	Fort Wayne.
Boltz, J. H	Winchester.	Schutt, M. A	Michigan City.
Dorsey, W. C	Terre Haute.	Derr, Walter	South Bend.
Carr, W. C	Crawfordsville.	Cornell, J. B	Goshen.

During the ten months of my administration of the office 43,706 barrels of oil were inspected by myself, and 152,694 by my deputies and assistants. Of this number 551 barrels were rejected. The standard test for all illuminating oils in Indiana is gravity test, Beaume's hydrometer, not below 46° nor higher than 50°. The said oils shall bear a flash test not below 120° Fahrenheit, and a fire test not below 140° Fahrenheit. This test is as high, if not higher, than that required by any other State in the Union. Much of the oil that was rejected would very likely have passed the inspection in other States, but it would not stand the test required by law in Indiana.

While the law concerning the inspection of oils has been generally obeyed, there have been a few intended violations of it. Two parties who persisted in selling uninspected oil in Vermillion and Fountain counties were arrested and fined $50.00 and costs each. At the present writing warrants are out for two additional violators of the law in the same section of the State. The uninspected oil sold was shipped into Indiana from Danville, Ill., and the Deputy Inspector in the Eighth District was not notified by the persons to whom it was consigned.

It is the duty of all Deputy Inspectors to prosecute any and all violators of the law and any failure to do so renders them at once liable to be removed, and at the same time fined in a sum not to exceed $500.

On account of the high test required and rigid inspection of the oil sold in the State no accident resulting from the use of illuminating oils has come to my notice, during my term of office. Some complaints have been made that the oil at present sold has a tendency to smoke the chimneys, but this is doubtless due to faults in the burner and wick used rather than in the oil itself.

The following table will show the total inspections for the ten months covered by this report, also the number of barrels inspected by the month.

Number of barrels approved	196,400
Number of barrels rejected	551
Total inspections for ten months	196,951

TABLE SHOWING INSPECTIONS BY MONTHS.

Months.	Approved.	Rejected.	Total.
March	20,936	123	21,059
April	17,228		17,228
May	11,036		11,036
June	10,369		10,369
July	10,760		10,760
August	14,567		14,567
September	19,520		19,520
October	27,469	428	27,897
November	32,904		32,904
December	31,611		31,611
Total	196,400	551	196,951

TABLE SHOWING INSPECTIONS BY STATIONS.

Stations.	Approved.	Rejected.	Total.
Evansville	14,487		14,487
Vincennes	7,153		7,153
New Albany	3,267		3,267
Jeffersonville	1,801		1,801
Madison	2,276		2,276
Brookville	1,675		1,675
Aurora	1,308		1,308
Greensburg	842		842
Rushville	1,450		1,450
Shelbyville	893		893
Columbus	1,443		1,443
Danville	976		976
Union City	1,020		1,020
Richmond	3,960		3,960
Muncie	1,448		1,448
Indianapolis	43,706	551	44,257
Terre Haute	10,249		10,249
Brazil	2,013		2,013
Crawfordsville	2,801		2,801
Lafayette	13,286		13,286
Kokomo	1,743		1,743
Logansport	6,920		6,920
Delphi	1,265		1,265
Rochester	488		488
Whiting	5,087		5,087
Hammond	3,234		3,234
Valparaiso	1,060		1.060
North Manchester	719		719

TABLE SHOWING INSPECTIONS BY STATIONS—Continued.

Stations.	Approved.	Rejected.	Total.
Peru	4,479		4,479
Marion	1,573		1,573
Huntington	1,616		1,616
Portland	120		120
Ft. Wayne	9,410		9,410
South Bend	6,024		6,024
Michigan City	1,623		1,623
Elkhart	4,046		4,046
Laporte	1,738		1,738
Warsaw	1,072		1,072
Goshen	1,851		1,851
Louisville, Ky	3,910		3,910
Cincinnati, Ohio	3,806		3,806
Toledo, Ohio	1,554		1,554
Lima, Ohio	10,679		10,679
Mansfield, Ohio	745		745
Cleveland, Ohio	4,456		4,456
Hamilton, Ohio	1,128		1,128
Total	196,400	551	196,951

TABLE SHOWING PLACE OF MANUFACTURE.

Whiting, Ind	57,805
Lima, Ohio	104,584
Toledo, Ohio	5,110
Pittsburgh, Pa	4,084
Franklin, Pa	148
Cleveland, Ohio	11,751
Findlay, Ohio	1,082
Oil City, Pa	5,259
Washington, Pa	4,273
Titusville, Pa	1,545
Reno, Pa	513
Bear Creek, Pa	120
St. Louis, Mo	135
Chicago, Ill	14
Buffalo, N. Y	123
Welker, Ohio	345
Marcus Hook, Pa	60
Total	196,951

TABLE SHOWING STATES WHERE OIL WAS MANUFACTURED.

Ohio	122,872
Indiana	57,805
Pennsylvania	16,002
Missouri	135
New York	123
Illlinois	14
Total	196,951

How much of the oil refined at Whiting, Ind., and Lima, O., is made from the crude petroleum produced in Indiana I have not been able to ascertain. The development of the petroleum industry in this State has continued to steadily advance, and during the year 1895 nearly three thousand new wells were put down, more than three-fourths of which proved productive.

Oil found in Ohio and Indiana comes from the Trenton limestone. It contains more sulphur and nitrogen than does the shale oil of Pennsylvania. For this reason it is of a darker color, higher specific gravity, and possesses a more rank and disagreeable odor. These properties diminish the commercial value of the Ohio and Indiana product to a considerable extent. During the oil boom in April, 1895, the highest point touched by the Pennsylvania oil was $2.70 per barrel, while the highest reached by the Ohio oil was $1.24; the Indiana product being about 10 cents less than the Ohio, though for no known reason, as the oil fields of the two States are doubtless continuous and the product essentially the same.

The following table shows the number of wells completed by months in Indiana during the year 1895, with the average daily production of each, and the number which proved dry; also, the number of wells being drilled and the rigs up on December 31, 1895:

NUMBER OF WELLS COMPLETED BY MONTHS IN 1895.

MONTHS.	Wells Completed.	New Productions, bbls.	Wells Dry.	Drilling.	Rigs Up.
January	222	3,150	99	201	137
February	171	2,425	72	155	111
March	235	3,095	83	187	131
April	256	4,163	76	223	343
May	311	5,014	86	289	345
June	240	4,730	59	250	314
July	262	5,235	57	282	326
August	236	4,750	50	212	239
September	272	5,220	57	284	144
October	204	3,690	42	222	135
November	150	2,565	34	175	81
December	152	2,305	39	158	62
Total	2,711	46,342	754	2,638	2,368

WELLS COMPLETED IN ADAMS COUNTY IN 1895, BY MONTHS.

MONTHS.	Wells Completed.	New Productions, bbls.	Wells Dry.	Drilling.	Rigs Up.
January	21	600	4	18	18
February	19	400	3	19	16
March	24	440	4	20	17
April	32	505	5	21	37
May	43	710	7	36	38
June	39	800	5	31	27
July	36	730	4	34	31
August	29	640	5	32	28
September	36	710	6	39	16
October	26	395	5	30	13
November	12	180	1	16	7
December	11	110	2	12	10
Total	328	6,210	51	308	258

WELLS COMPLETED IN BLACKFORD COUNTY IN 1895, BY MONTHS.

MONTHS.	Wells Completed.	New Productions, bbls.	Wells Dry.	Drilling.	Rigs Up.
January	10	100	5	5	5
February	5	20	3	3	8
March	12	330	3	16	9
April	14	450	4	17	21
May	16	504	5	19	23
June	13	500	4	16	21
July	17	670	3	21	22
August	21	700	2	16	8
September	24	605	4	21	12
October	11	230	3	9	18
November	13	205	2	12	11
December	12	140	3	9	5
Total	165	4,454	41	164	163

WELLS COMPLETED IN GRANT COUNTY IN 1895, BY MONTHS.

MONTHS.	Wells Completed.	New Productions, bbls.	Wells Dry.	Drilling.	Rigs Up.
January	28	350	12	21	8
February	21	310	13	11	5
March	16	205	9	13	6
April	15	135	8	12	32
May	27	315	9	26	29
June	12	210	4	16	31
July	14	305	6	12	24
August	15	300	5	10	21
September	31	645	7	19	11
October	29	620	2	27	21
November	20	340	4	21	12
December	23	305	5	22	8
Total	251	4,040	84	210	208

WELLS COMPLETED IN HUNTINGTON COUNTY IN 1896, BY MONTHS.

MONTHS.	Wells Completed.	New Productions, bbls.	Wells Dry.	Drilling.	Rigs Up.
January	6	150	3	5	6
February	7	125	3	6	7
March	6	60	3	5	3
April	7	200	2	8	13
May	10	235	3	13	17
June	6	120	3	16	19
July	5	120	2	15	18
August	3	60	....	8	16
September	6	75	2	6	9
October	7	105	2	4	8
November	2	10	....	3	4
December	6	100	2	4	5
Total	71	1,360	25	93	125

WELLS COMPLETED IN JAY COUNTY IN 1896, BY MONTHS.

MONTHS.	Wells Completed.	New Productions, bbls.	Wells Dry.	Drilling.	Rigs Up.
January	36	810	6	35	32
February	24	530	5	26	23
March	41	610	6	31	24
April	46	707	6	35	44
May	57	905	9	47	51
June	46	810	7	40	60
July	51	940	9	51	70
August	46	810	8	38	42
September	51	905	9	46	21
October	30	410	10	31	12
November	19	220	6	26	6
December	21	210	6	22	8
Total	468	7,897	85	428	393

WELLS COMPLETED IN WELLS COUNTY IN 1896, BY MONTHS.

MONTHS.	Wells Completed.	New Productions, bbls.	Wells Dry.	Drilling.	Rigs Up.
January	58	1,060	7	56	44
February	51	940	5	44	31
March	67	1,120	6	62	43
April	80	1,863	7	87	99
May	97	2,130	11	96	101
June	83	1,845	10	94	102
July	104	2,160	9	103	99
August	98	2,040	11	86	84
September	103	2,160	13	126	62
October	89	1,910	13	96	44
November	71	1,605	9	81	32
December	62	1,410	7	60	21
Total	963	20,243	108	991	762

WELLS COMPLETED IN ALL ADDITIONAL COUNTIES IN INDIANA IN WHICH DRILLING FOR OIL WAS DONE IN 1895, BY MONTHS.

MONTHS.	Wells Completed.	New Productions, bbls.	Wells Dry.	Drilling.	Rigs Up.
January	66	50	62	61	24
February	44	100	40	48	21
March	69	330	52	41	29
April	62	303	44	43	97
May	61	215	42	52	86
June	41	445	26	37	54
July	35	310	24	46	62
August	24	200	19	22	40
September	21	120	16	27	13
October	12	30	9	22	19
November	13	5	12	16	8
December	17	30	14	29	6
Total	465	2,138	360	444	459

In conclusion, I will say that in my opinion the law regulating the inspection of oil is accomplishing all that its originators intended. It has resulted in a much better grade of oil being furnished to the consumers than was done before its enactment. As a result the loss of life and property due to explosions has been reduced to a minimum. All of this has been brought about without cost to the tax-payers of the State, as the expense of inspection is wholly borne by the oil companies.

Respectfully submitted,

C. F. HALL.

THE CRAWFISHES OF THE STATE OF INDIANA.

BY W. P. HAY, M. S.

PROF. W. S. BLATCHLEY,
Indianapolis, Ind.:

DEAR SIR—I herewith present to you my report on the crawfishes of the State of Indiana In the following pages I have brought together a set of descriptions taken from Indiana types of the species which occur within the limits of the State. Keeping constantly in mind the needs of the teacher and student, I have made my descriptions full and at the same time as simple as the subject would permit. As a further aid in identification I have prepared for each species a set of camera lucida drawings to show the characteristic features. The analytical key will also be found of the greatest assistance to the worker. Along with the descriptions I have for each species mentioned the various points in our State in which it has been taken. Until the distribution of the crawfishes is more thoroughly worked up it would hardly be safe to express in general terms the extent of country over which a species is to be found.

I have also added in most cases a few notes regarding the habits. Comparatively few observations have been made in this line and I regret exceedingly that that part of my paper has been curtailed. Throughout my work I have had constantly at my hand the works of Drs. Hagen and Faxon on the crawfishes of North America, and I have used them freely whenever I have had occasion to do so.

To Dr. Faxon, I wish to express my thanks for his suggestions regarding the new species herein described.

To the following gentlemen I am very much indebted for the loan of specimens and other favors, without which it would have been almost impossible to have completed my work: Prof. B. M. Davis, Butler College; Dr. C. H. Eigenmann, Indiana State University; Prof. A. C. Yoder, Vincennes High School; Prof. J. T. Scovell, Terre Haute High School; Dr. O. P. Hay, Field Columbian Museum; Prof. W. W. Wright, Oberlin College, Ohio; Prof. B. W. Evermann, U. S. Fish Commission; Dr. G. Brown Goode, Director, and Mr. J. E. Benedict, Assistant Curator, Department of Marine Invertebrates, U. S. National Museum.

WASHINGTON, D. C., December, 1895.

INTRODUCTION.

The genus Cambarus.—This genus, which was proposed by Erichson in 1846 to contain certain peculiar crawfishes of the American continent, forms one division of the family *Astacidæ*, a family which is very closely related to the *Homaridæ*, or lobsters, and from which they are distinguished by the fact that the segment bearing the hindmost pair of walking legs is not immovably fused to the one preceding it, but is capable of motion back and forth.

The crawfishes then may be briefly described as long-tailed, ten-legged crustaceans (contrasted with the crabs) having the anterior portion of the body covered with a shell or *carapace*, which ends in front in a prominent beak or *rostrum*, and which is divided near the middle by a transverse groove, *cervical groove*. The first pair of walking legs is much enlarged, end in pincers and serve as organs of offense and defense. The second and third pairs of walking legs are much smaller, but likewise end in pincers. The fourth and fifth pairs are not so provided and the latter pair of legs are borne on a segment which is not fused with the one in front. The family is divided into two groups or sub-families.

1. The *Astacinæ*, which includes those crawfishes having the first pair of abdominal appendages in the male modified to form sexual organs. This group is divided into two genera, *Cambarus* and *Astacus*, both of which are found, so far as known, only in the northern hemisphere.

2. The *Parastacinæ*, including those crawfishes in which the first pair of abdominal appendages in both sexes is entirely wanting. This group is divided, at present, into six genera, *Astacoides*, *Cheraps*, *Engaeus*, *Paranephrops*. *Astacopsis* and *Parastacus*, all of which are found south of the equator and which probably never range far north of it.

In North America both genera of the *Astacinae* are found. *Astacus*, however, occurs only west of the Rocky Mountains and in the Yellowstone River, while all the species to the eastward belong to the genus *Cambarus*. *Cambarus* is distinguishable from *Astacus* by the following characters: (1) the last body segment is not provided with a gill; (2) in the male one or two pairs of thoracic legs bear on the lower surface of the third segment a strong re-curved projection or hook, and the first pair of abdominal appendages end in two distinct branches; (3) in the female there is on the lower surface of the body, between the fourth and fifth pairs of walking legs, a peculiar irregularly conical elevation with a depressed and deeply furrowed apex—the *annulus ventralis.*

The number of described species of *Cambarus* is at present sixty-one; the only form which occurs beyond the limits of the North American continent being *C. typhlobius* Jos., a blind species from the caves of Carniola, in Austria. Of the genus *Astacus* only fourteen species are known from Europe, Asia and North America together.

In habits there is a greater variation among the species of crawfishes than is generally supposed. Some inhabit only streams of pure running water, others are to be looked for in lakes and standing pools, and others visit the streams only during the spawning season. Some species lead a roving life; others spend most of their time hiding under stones or other objects in the water; others dig burrows into the banks of the stream and from these tunnels sally forth to catch some unfortunate animal as it passes by; three of our species, at least, dig complicated burrows, often some distance from the water, and erect over the holes a carefully constructed chimney.

The food of these animals probably varies to almost as great an extent as their habits, but concerning this but little is known. Some forms are undoubtedly carnivorous, while for others the evidence, which, however, is scant, points toward a diet that is very largely vegetable.

Specific Characters. In the genus *Cambarus* the variations among the individuals are frequently perplexing; they are greater than among most animals.

A crawfish apparently grows indefinitely, and with the increase in age come more or less marked changes, not only in size but in the form and proportions of the parts. In species which in the adult condition are smooth the young are very apt to show spines on the rostrum or sides of the carapace. In species which bear spines the older individuals are often better provided with these means of defense than the young

Accidental variations are always to be looked for. As is well known, a crawfish is able to reproduce lost appendages, and as appendages are very easily lost it is no unusual thing to find the large claw on one side very unlike its mate on the other side, or to find one antenna long and slender, while the other is a mere stump. These variations will never be misleading unless they happen to be exactly alike on the two sides, a thing which sometimes occurs.

Between the two sexes there is a difference which extends to almost all parts of the body. The female has a wider abdomen bearing stronger swimmerets, usually a less developed armature, and weaker and smaller claws. The amount of these sexual differences is variable, however, owing to the fact that for each species there are two forms of the male; of which one is more highly developed, better armed and fitted for sexual union with the female. The other is apparently sterile and bears a close resemblance to the opposite sex. In a paper "On the so-called Dimorphism in the Genus Cambarus" (Amer. Jour. Sci., xxvii, Jan. 1884), Dr. Faxon calls attention to the discovery that these two forms are simply phases in the life of the same individual; that during the pairing season the characteristics of the "first form" are assumed, and after a completion of the sexual union, a moult brings the animal into the "second form," another moult being necessary before the animal is again capable of reproduction.

For dividing the genus into subordinate groups various characters have been drawn into service, the most satisfactory, however, are those employed by Dr. Faxon, viz., the number of hooked legs in conjunction with the character of the first abdominal appendages of the male. As will be seen, for the successful identification of any species, specimens of the female alone will be of little value. Such a method is open to criticism, but it is the only one which seems to be a natural one, and, after all, the difficulties are more imaginary than real.

The following analytical key will facilitate the identification of the fifteen species known to occur in Indiana:

1. Third segment of third and fourth pairs of legs of males hooked.
    - a. Eyes well developed. *C. blandingii acutus* (p. 481).
    - b. Eyes atrophied.
        - 1. Carapace and rostrum with spines. *C. pellucidus* (p. 482).
        - 2. Carapace and rostrum smooth. *C. pellucidus testii* (p. 484).
2. Third segment of only the third pair of legs of male hooked.
    - A. First pair of abdominal appendages of the male claviform, the outer part truncate and terminated by three small teeth, inner part ending in a slender spine. *C. gracilis* (p. 486).
    - B. First pair of abdominal appendages of the male ending in two thick falciform teeth, the larger of which is formed by the outer part of the appendage, the smaller by the inner part.
        - 1. Areola linear or obliterated in the middle.
            - a. Anterior border of the carapace with a projecting angle below the eye. *C. diogenes* (p. 489).
            - b. Anterior border of the carapace without a projecting suborbital angle. *C. argillicola* (p. 492).
        - 2. Areola moderately wide. *C. bartonii* (p. 487).
    - C. First pair of abdominal appendages of the male furciform, ending in two nearly straight branches.
        - 1. Rostrum without lateral spines. *C. immunis* (p. 501).

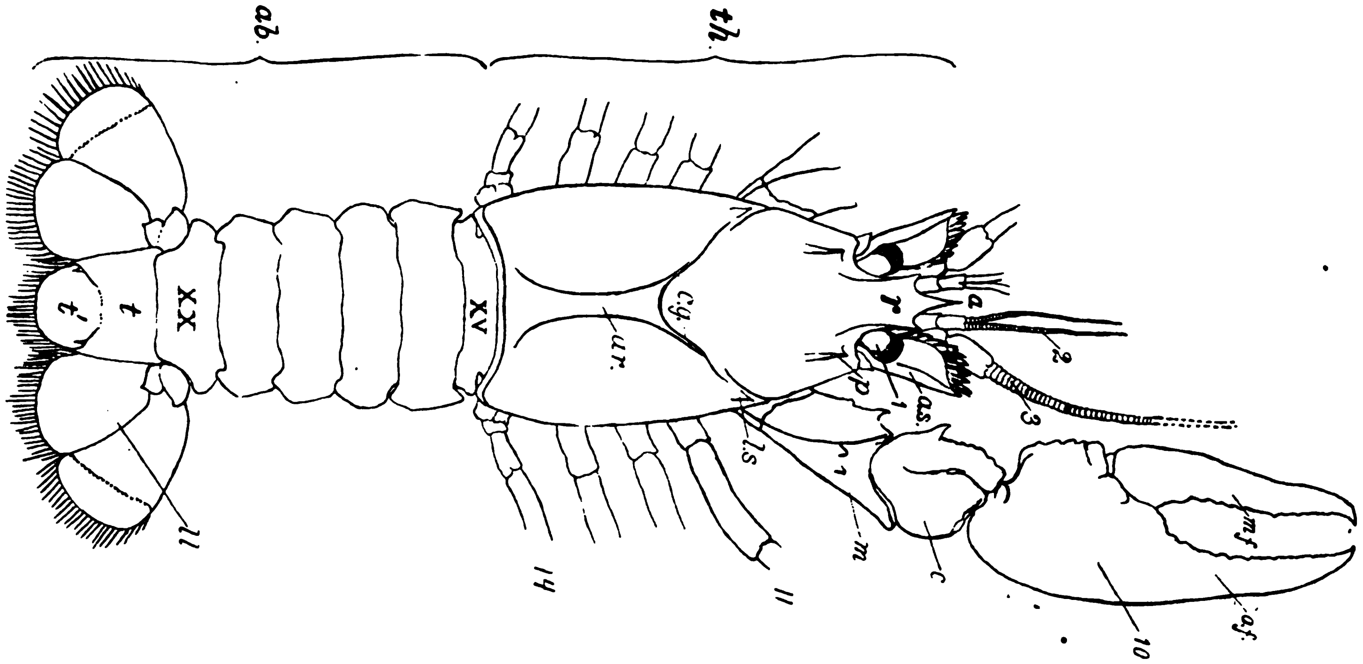


FIG. 1. Dorsal view of *Cambarus rusticus*, male. 1, eye; 2, antennule; 3, antennæ; 10, chela; 11, second pair of walking legs; 14, fifth pair of walking legs; XV–XX, segments of the abdomen; *a*, acumen of rostrum; *ab*, abdomen; *a. s.*, antennal scale; *ar*, areola; *c. g.*, cervical groove; *c*, carpus; *ll*, lateral lobe of tail fin; *l. s*, lateral spine; *m*, meros; *m. f.*, movable finger; *o. f.*, outer finger; *p*, post orbital spine; *t*, proximal, *t'*, distal segments of telson; *th*, thorax covered by the carapace.

2. Rostrum with lateral spines.
   a. Rostrum with a median longitudinal ridge above. *C. propinquus* (p. 497).
   b. Rostrum without such a ridge.
1. First pair of abdominal appendages very long and deeply cleft, reaching the base of the chelipeds when the abdomen is flexed. *C. putnami* (p. 504).
2. First pair of abdominal appendages shorter, not reaching the base of the chelipeds.
   a. Sides of the rostrum concave.
      1. Incurvation decided. *C. rusticus* (p. 503).
      2. Incurvation slight. *C. indianensis* (p. 494).
   b. Sides of the rostrum not concave.
      1. Rami of the first abdominal appendages strongly recurved near the tips. *C. immunis spinirostris* (p. 502).
      2. Rami of the first abdominal appendages nearly straight.
         a. Rami long and slender. *C. virilis* (p. 499).
         b. Rami short and thick. *C. sloanii* (p. 495).

CAMBARUS BLANDINGII ACUTUS (Girard).

Cambarus acutus Girard, Proc. Acad. Nat. Sci., Phila., VI, 91, 1852.
Cambarus acutus Hagen, Ill. Cat. Mus. Comp. Zoöl. No. III, p. 35.
Cambarus blandingii var. *acuta* Faxon, Mem. Mus. Comp. Zoöl. X, No. 4, 1885, p. 20.

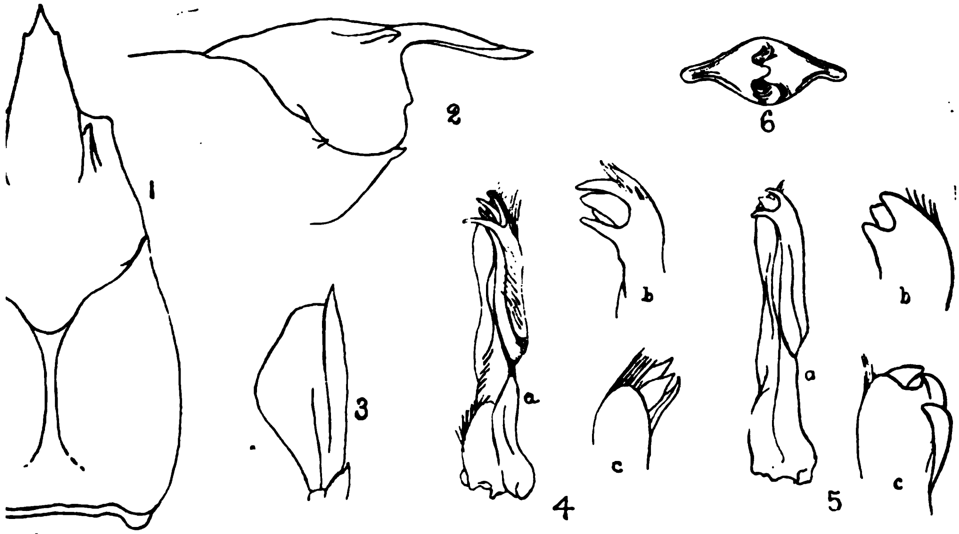


FIG. 2. *Cambarus blandingii acutus.*—1, carapace from above; 2, carapace from side; 3, antennal scale; 4, first abdominal appendage, male, F. I; 5, first abdominal appendage, male, F. II; 6, annulus ventralis.

Male, Form I.—Rostrum triangular, broad at the base, with sharp, raised and convex margins; acumen short, lateral teeth small; post orbital spine small, ridges grooved externally, nearly parallel in front, but strongly converging behind. Carapace oval, not flattened, nearly smooth about the base of the rostrum, otherwise strongly tuberculate. Cervical groove rather deep, sinuate, broken on the sides and ending above the small branchiostegal spine. Areola rather narrow. Abdomen shorter than the cephalothorax, well arched, and with nearly parallel sides. Telson with the posterior border sinuate, proximal segment bispinose on each side. Tail fin when extended equal in width to length of abdomen. Antennæ slender, shorter than the body; scale slightly longer than the rostrum, widest near the middle, truncate at apex, with a short, terminal spine, border inflated Epistoma triangular and densely fringed with hairs. Third maxillipeds, hairy below, within and without. Chelipeds slender; meros, in perfect specimens, surpassing the tip of the rostrum;

chelæ slender, rounded and heavily granulate or squamous, internal margin strongly dentate; fingers slender, external one nearly straight, internal one sinuate. Carpus long, nearly flat above, inner surface with several strong spines. Meros slender, a ridge of small blunt spines above and an irregular double line of larger spines below. Third and fourth pairs of legs hooked, the hooks on the third pair being the largest and strongest. First pair of abdominal appendages short, straight and thick, apex plainly bifid; external part the strongest, bearing, at the extremity, two curved, acute, horny spines and a pencil of hairs; internal portion ending in two slender spines.

Male, Form II.—Similar in general to Form I, but with smaller hooks on the third and fourth pairs of legs. The first abdominal appendages have an articulation near the base, apical teeth on both the internal and external portions small and blunt, and the pencil of hairs almost gone.

Female.—Similar, but with shorter chelæ and smoother carapace. Annulus ventralis much wider than long, with a deep longitudinal fissure dividing it, the sides of the fissure near the middle being raised into a prominent elevation or tubercle on each side, and the tubercle of one side often overhanging that of the other.

Measurements of male, Form I—Length, 93 mm.; carapace, 49 mm.; abdomen, 44 mm.; rostrum to cervical groove, 31.5 mm.; rostrum, 12 mm.; breadth of rostrum, 7 mm.; areola, 2 mm.; carapace, 23 mm.; second abdominal segment, 19 mm.

Indiana Localities—Wheatland and Vincennes, Knox county; Turkey Lake, Kosciusko county; Lake Maxinkuckee, Marshall county; Kankakee River, Lake county; Terre Haute, Vigo county.

Cambarus blandingii acutus is to be looked for in almost any character of surroundings. Usually, however, they occur in running water where there is an abundant supply of vegetation.

CAMBARUS PELLUCIDUS (Tellkampf).

Astacus pellucidus Tellkampf, Arch. Anat. Physiol. u. Wissensch. Med., 1844, p. 383.

Cambarus pellucidus Hagen, Ill. Cat. Mus. Comp. Zoöl., No. III, p. 55, 1870.

Cambarus pellucidus Faxon, Mem. Mus. Comp. Zoöl., X, No. 4, p. 40, 1885.

Cambarus pellucidus Hay, Proc. U. S. Nat. Mus., Vol. XVI, pp. 283–286, 1893.

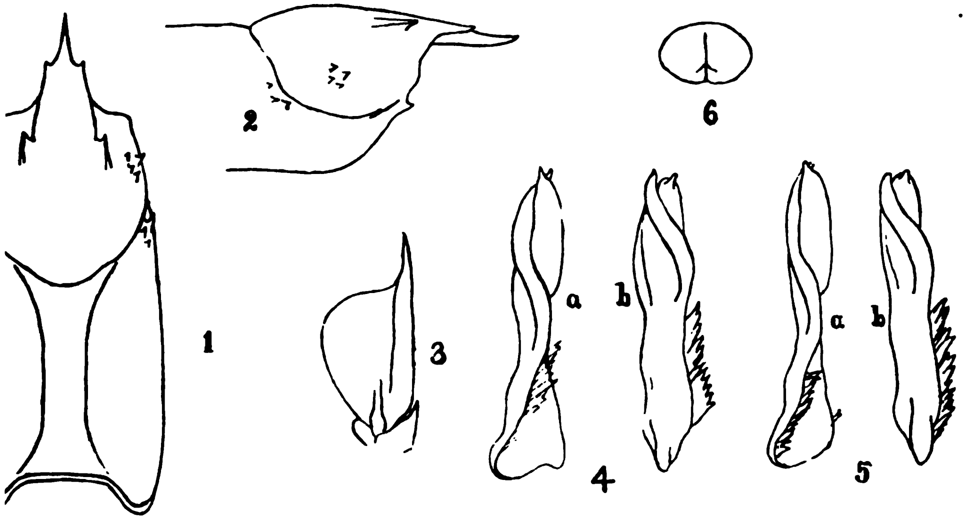


FIG. 3. *Cambarus pellucidus.*—1 and 2, carapace from above and side; 3, antennal scale; 4, first abdominal appendage male, F. I; 5, same, F. II; 6, annulus ventralis.

Male, Form I.—Rostrum broad, smooth, and with a shallow foveola at the base; margins raised and somewhat converging; rostral spines well developed, slightly turned outward; acumen usually very long and slender. Postorbital spines acute, the ridges very low. Carapace cylindrical, smooth above, granulate on the sides; lateral spines numerous and directed obliquely outwards; areola long, sides nearly parallel. Abdomen with nearly parallel sides, pleural angles obtuse; telson tapering slightly to the evenly rounded extremity, proximal segment bi-spinose on each side. Eyes atrophied, appearing as small white lumps hidden beneath the rostrum. Antennæ longer than the body, scale about as long as the rostrum, widest near the end. Epistoma short and broad, the margins straight and swollen. Third maxillipeds hairy within Chelipeds slender and long, the distal end of the meros reaching the tip of the rostrum. Hand slender, covered with granulations which on the inner border are larger and tooth-like; movable finger nearly straight, the tip strongly incurved. Carpus long, only slightly grooved above, the inner surface bearing several small spines. Meros with a longitudinal band of spines on both upper and lower surfaces. Hooks on the third and fourth pairs of legs very strong and tooth-like, those on the third legs strongest. First pair of abdominal appendages short, straight and twisted at the apex, inner ramus bearing on its apex a small outwardly directed tooth, which, as well as the tip of the outer ramus, is brown and corneous.

Male, Form II.—Very similar, the hooks on the third and fourth pairs of legs are not so strong, the first abdominal appendages have a smaller apical tooth and the tips of the rami are not corneous.

Female.—More slender, with weaker chelæ. Annulus ventralis an elliptical papilla crossed by a narrow, longitudinal line, which on the posterior face gives off a small oblique branch on each side.

Measurements of male, Form I—Length, 68 mm.; carapace, 32 mm.; abdomen, 36 mm.; rostrum to cervical groove, 19.5 mm.; rostrum, 8.5 mm.; breadth of rostrum, 4 mm.; carapace, 12 mm.; areola, 2 mm.; 2d abdominal segment, 11 5 mm.

Color in life a translucent creamy white, the stomach showing through as a bluish spot in front of the cervical groove.

Indiana Localities.—Shiloh Cave, Down's Cave, Dunnihue's Cave, Connelly's Cave, Donelson's Cave, Lawrence county; cave at Clifty, Bartholomew county; cave near Paoli, and in Lost River, Orange county; Wyandotte Cave, Wildcat Cave, small cave near Wyandotte, and Marengo Cave (?), Crawford county; "caves in Harrison county;" caves near Madison, Jefferson county.

Cambarus pellucidus was first described from specimens from the Mammoth Cave of Kentucky. It was discovered to occur in Wyandotte Cave by Prof. E. D. Cope, in 1871, and in 1872 he described it as a new species and genus *Orconectes inermis*, establishing the new genus to contain all the blind crawfishes.

The generic differentiation met with no acceptance, and the form "*inermis*" is now hardly recognized even as a variety of pellucidus. The species is extremely variable in such points as the length of the rostrum and the arrangement of spines This variation I have found most marked in specimens taken from the caves of Lawrence and Monroe counties. In Shiloh Cave, near Bedford, I have collected a series of between forty and fifty specimens. Among them I find individuals which agree almost perfectly with specimens from Mammoth Cave, and other individuals which are almost entirely destitute of spines. From the caves of Monroe county comes a peculiar form which is entirely without spines on the carapace. So constant is this feature and so different is the appearance of these specimens that I have separated them as a subspecies.

CAMBARUS PELLUCIDUS TESTII Hay

Cambarus pellucidus Packard. Monograph Cave Animals of N. A., Mem. Nat. Acad. Sci. Vol. IX, No. 9, p. 16, 1888.

Cambarus pellucidus Faxon. Notes on N. A. Crayfishes, Proc. U. S. Nat. Museum, Vol. XII, p. 621, 1890.

Cambarus pellucidus testii Hay. Proc. U. S. Nat. Museum, Vol. XVI, pp. 283–286, 1893.

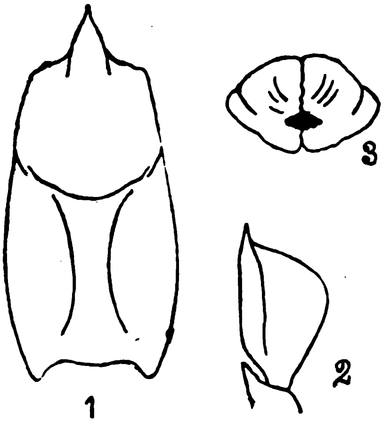


FIG. 4. *Cambarus pellucidus testii.*—1, carapace from above; 2, antennal scale; 3, annulus ventralis.

Differs from *C. pellucidus* in the great reduction of the spines. Instead of being rough and very spiny, as the typical specimens from Mammoth Cave are described as being, they are entirely smooth. The lateral rostral spines are wholly gone, the post-orbital ridges are smooth and rounded at the end, and the lateral spines of the carapace are at best represented by a few low, smooth tubercles.

The rostrum is shortened still more than in Prof. Cope's *inermis*, and instead of being "deeply sinuated to form the acumen," runs to a point in a gradual curve, very much resembling in this respect *C. acuminatus*.

The portion of the carapace in front of the cervical groove is shorter than in the average of specimens from Shiloh Cave, and conspicuously shorter than in specimens from Mammoth Cave. In respect to the hooks on the legs of the males I find the species variable. In none do I find hooks on both legs of the fourth pair; generally they are wholly wanting, but in some there is a small tubercle on one leg, which is missing from the other The hooks on the third pair of legs are of a slightly different form from those of specimens from Shiloh or Wyandotte. They are shorter, blunter, and not curved.

The first abdominal appendages of the males do not differ in any respect from those of the typical *C. pellucidus*.

In the female the annulus ventralis shows marked differences from the typical forms.

The antennal scale, also, is different in form, and especially in length.

Indiana Localities—Mayfield's and Truett's Caves, Monroe county.

CAMBARUS GRACILIS Bundy.

Cambarus gracilis Bundy, Bull. Ill. Mus. Nat. Hist., No. 1, p. 5, 1876.
Cambarus gracilis Faxon, Mem. Mus. Comp. Zoöl., Vol. X., No. 4, p. 56, 1885.

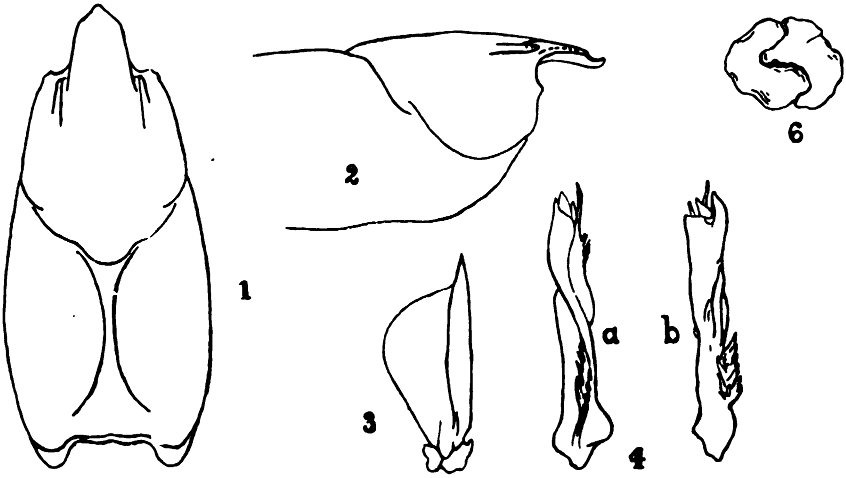


FIG. 5. *Cambarus gracilis*—1 and 2, carapace from above and side; 3, antennal scale; 4, first abdominal appendage, male F. I; 6, annulus ventralis.

Male, Form I.—Rostrum of moderate length, decurved, much hollowed out, with a small foveola at base; margins prominent, converging slightly to near the tip, where they suddenly turn inward to form the short acumen, sides of the acumen slightly concave. Post-orbital ridges grooved on outer face, without spines in front, and slightly inflated at the posterior ends. Cephalothorax long and compressed. Carapace nearly smooth above, granulate on the sides, a small projecting angle just below the eye. Cervical groove markedly sinuate, broken on the sides; no lateral or branchiostegal spine; areola linear, with a small anterior and a larger posterior triangular space. Abdomen shorter than the cephalothorax; pleural angles truncate; telson short; proximal segment uni- or bi-spinose on each side, distal segment rounded; inner blade of swimmeret with a short curved ridge on the inner margin, the main longitudinal rib not reaching the distal end of the blade. Antennæ slender, about as long as distance from cervical groove to end of telson; scale small, about as long as rostrum, widest beyond the middle; terminal spine acute. Epistoma triangular, sides straight or convex, anterior angle truncate or dentate. Inner face of third maxillipeds furnished with long hairs. Chelipeds stout and rather short; chelæ swollen and covered with punctations; inner margin serrate; fingers somewhat flattened and decurved; movable finger sinuate, serrate on external margin near the base and bearing one or more strong tubercles on the internal margin, tip incurved, acute and corneous; outer finger nearly straight, with a large tooth on the internal margin near the base; tip acute and corneous. Carpus triangular, with a large tooth and two or three small tubercles on the inner face and several strong teeth below, furrow on upper surface deep and broad. Meros with a few spines above near the distal end, lower surface with two rows of small spines. The two distal joints of the second, fourth, and fifth legs hairy. Third pair of legs hooked. Sternum hairy. First pair of abdominal appendages rather long (reaching to the base of the third pair of legs), twisted, internal portion short, terminated by a long, slender spine and bearing a prominent tuft of hair near the middle; external portion of appendage notched at the apex; posterior portion prolonged into a flattened, corneous, tooth-like process; anterior portion acute and tooth-like. Between these two elevations are two slender teeth.

Male, Form II.—Not known.

Female.—Very similar to the male. . Annulus ventralis movable, composed of two interlocked falciform pieces, highest on the outer margins. Openings of oviducts surrounded by long hairs.

Measurements of male, Form I.—Length, 62; carapace, 32.5; abdomen, 29.5; rostrum to cervical groove, 19; rostrum, 6. Breadth—carapace, 14; rostrum, 4.25; second abdominal segment, 12.

Cambarus gracilis, as far as I have been able to learn, has never been taken in Indiana, and, therefore, ought possibly to be excluded from this list. I have lately, however, received a specimen of this species from the neighborhood of Chicago, and I think there can be no doubt of its occurrence in the prairie region in the western portion of our State. In its habits it is a burrower, coming forth probably only during the breeding season, in the early spring, when it frequents the water courses.

Cambarus bartonii (Fabricius).

(?) *Astacus bartonii* Fabricius, Suppl. Entomolog. Systemat., p. 407, 1798.

Cambarus bartonii Hagen, Ill. Cat. Mus. Comp. Zoöl., No. III, p. 75, 1870.

Cambarus bartonii Faxon, Mem. Mus. Comp. Zoöl., Vol. X, No. 4, p. 59, 1885.

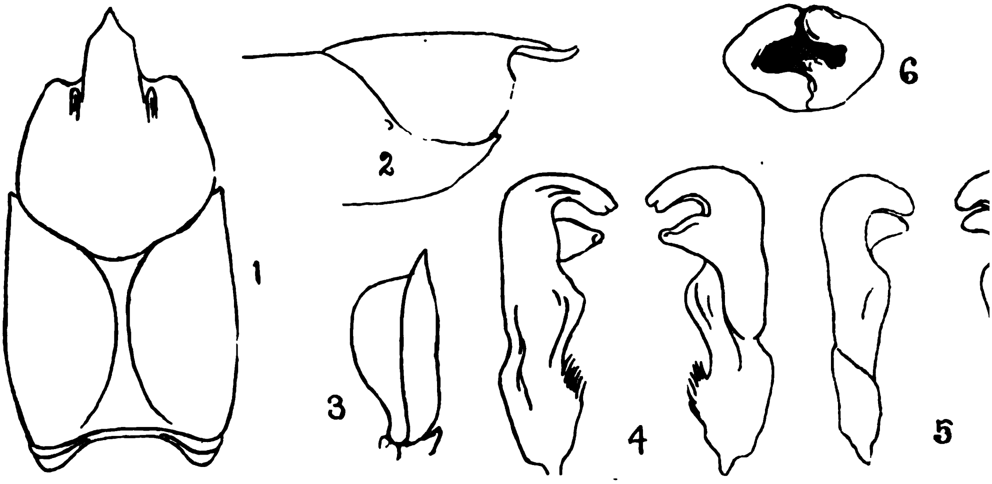


FIG. 6. *Cambarus bartonii.*—1 and 2, carapace from above and from the side; 3, antennal scale; 4, first abdominal appendages, male, F. I; 5, same, F. II; 6, annulus ventralis.

Male, Form I.—Rostrum short, broad, and little excavated; margins low, converging; acumen short, with concave sides and brown, upturned horny tip. Post-orbital ridges low, short, grooved on outer face. Carapace much flattened above and quite smooth, slightly granulate on the sides, this most marked in front; lateral spines very minute, branchiostegal spine small; lateral line sinuous, not broken on the sides; areola narrow, anterior triangular space almost obsolete. Abdomen broad, about as long as carapace, telson tapering, proximal segment bispinose on each side, distal segment rather elliptical than rounded. Antennæ stout, shorter than the body; scale small, about as long as the rostrum, widest near the truncate tip; terminal spine small. Epistoma semicircular with a projecting median tooth. Third pair of maxillipeds hairy on the inner face. Chelæ strong, swollen and thickly punctate above inner border of the hand with a series of blunt serrations; movable finger squamoso-tuberculate on external border and with a prominent smooth rib above, tip incurved, brown and horny; outer finger stout, tip incurved and horny, also with a smooth rib above and with a nearly straight, denticulated inner border; tips of both fingers decurved. Carpus strong, deeply furrowed above, with a strong spine on the inner face and with two or more blunt tubercles on the distal end below. Second pair of legs quite hairy on the two or three terminal segments. Third pair of legs hooked. Fourth pair of legs with a rounded knob on the basal segment inside. First pair of abdominal appendages short, strong, twisted and consisting of two hook-like pieces one above the other; the upper hook, formed by the outer branch of the appendage is long, thin and horny; the lower hook, formed by the inner branch of the appendage, is short, thick, and bears at its extremity a small outwardly directed tooth.

Male, Form II.—Similar; first abdominal appendages with an articulation at the base, the terminal hooks are shorter, blunt and swollen.

Female.—Chelæ smaller and weaker; annulus ventralis wider than long, anterior wall not present, posterior wall raised into a strong, sharp, transverse ridge; longitudinal fissure wide in front, but narrowing behind where it crosses the ridge.

Measurements of male, Form II.—Length, 71.5; carapace, 35; abdomen, 36.5; rostrum, 6; rostrum to cervical groove, 20.5. Breadth, carapace, 18; rostrum, 4.5; areola, 1; 2d abdominal segment, 17.

Indiana Localities.—Fall Creek, Indianapolis, Irvington, Marion county; Bloomington, Clear Creek, May's Cave, Monroe county; Down's Cave, Connelly's Cave, Lawrence county; cave near Paoli, Orange county; New Albany, Jefferson county.

As is seen, this species is frequently found in caves in company with the true cave crawfish, *C. pellucidus*. In fact the largest and best developed specimens I have ever taken have been in the limestone caves of Southern Indiana. It is to be looked for, however, in almost any spring or stream of clear running water where it hides under stones or digs short burrows into the banks. That this habit of living in cold water is not a fixed one, is shown by the fact that Dr. Faxon mentions specimens taken from a spring in Clarke county, Va., the temperature of whose water is 67°F.

The Indiana types differ from individuals from the Eastern United States in having a narrower areola, less spiny carpus, and shorter and broader rostrum.

CAMBARUS DIOGENES Girard.

Cambarus diogenes Girard, Proc. Acad. Nat. Sci. Phila., No. VI, p. 88, 1852.

Cambarus obesus Hagen, Ill. Cat. Mus. Comp. Zoöl., No. III, p. 81, 1870.

Cambarus diogenes Faxon, Mem. Mus. Comp. Zoöl., Vol. X, No. IV, p. 71, 1885.

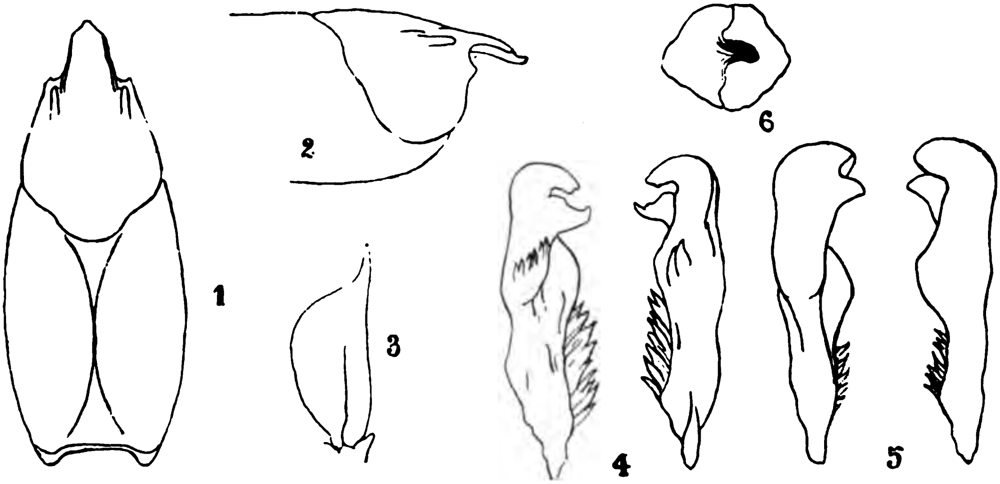


FIG. 7. *Cambarus diogenes.*—1 and 2, carapace from above and from the side; 3, antennal scale; 4, first abdominal appendage, male, F. I; 5, same, F. II; 6, annulus ventralis.

Male, Form I.—Rostrum short, broad, well excavated, down-curved, and without lateral spines; acumen short and triangular, its margins concave and the terminal spine turned abruptly upward. Post-orbital ridges low, grooved externally, swollen posteriorly, and without spines. Cephalothorax compressed, much contracted behind. Carapace smooth above, very lightly granulate on the sides; anterior border with a projecting angle just below the eye; cervical groove deep and sinuate, no lateral or branchiostegal spines. Areola linear, with a small anterior and a larger, poorly defined triangular area behind. First abdominal segment very narrow, second wider, about equal to carapace. Abdomen shorter than cephalothorax, pleural angles rounded; telson narrow, rounded behind, proximal segment bispinose on each side. Antennæ slender, shorter than the body, scale small, shorter than the rostrum, broadest at the middle. Epistoma triangular, the margins convex, as long as wide. Third maxillipeds with long hairs on inner face. Chelipeds large and strong, chelæ swollen and heavily punctate, inner margin of the hand tuberculate. External finger flattened on outer margin and with a row of dots along the inner margin close to the cutting edge, tip corneous and slightly incurved, cutting edge with a few tubercles; movable finger tuberculate at the base on both inner and outer margins, tip corneous and strongly incurved. Carpus short and thick, deeply furrowed above, with a small blunt spine on the inner surface and two small spines beneath. Meros thick and strong, with two small, blunt spines above and a double row of small spines below. Distal joints (2) of second, fourth and fifth walking legs hairy. Third pair of legs hooked. First pair of abdominal appendages thick and short, ending in two recurved, falciform, teeth placed one above the other; the lower is large, strong and turned upward at the tip; it is formed by the inner part of the appendage; the upper tooth is thin and corneous.

Male, Form II.—Very similar, chelæ possibly a little smaller in proportion; first abdominal appendages with the teeth nearly equal in size, and blunt

Female.—Similar, but with shorter antennæ, weaker chelæ, and broader and longer abdomen. Annulus ventralis about as long as wide, consisting of two interlocked irregularly crescentic portions which are raised around the margins into a prominent, rounded ridge. Openings of oviducts surrounded by a fringe of hair.

Measurements of male, Form I.—Length, 110; carapace, 57; abdomen, 53; rostrum, 11; tip of rostrum to cervical groove, 32; chela, 51.5. Breadth, carapace, 26; rostrum, 8; 2d abdominal segment, 20; chela, 22; areola, 0.

Color, a translucent, dark olive green, lighter and slightly flesh-tinted on the sides, margins of abdomen, rostrum and ends of chelae, red.

Indiana Localities.—Long Lake, Noble county; Kokomo, Howard county; Mechanicsburg, Henry county; Kankakee River, Riverside; Irvington, Marion county; Greencastle, Putnam county; North Salem, Hendricks county; Bloomington, Monroe county.

Cambarus diogenes will, in all probability, be found to occur in abundance in almost all portions of the State. It is a burrowing species, and with the next, *C. argillicola*, makes known its presence by raising above its burrows a chimney-like structure of mud pellets. The subterranean tunnels may sometimes be found to extend for several feet, and as the animal frequently excavates them at some distance from the water, they must reach a depth great enough to supply moisture sufficient for the needs of the animal. During the dry months of the summer, however, they seem to lie at the end of their burrows in a sort of stupor. I have seen them fall from the sides of an excavation apparently lifeless, but capable of reviving if put into water. In the early spring, when they come forth to breed, is the only season when they are a noticeable member of our fresh-water fauna. They move about chiefly at night, though I have frequently taken numbers of them from ditches and small streams on bright, sunny days. Of a lot of thirty-five specimens collected on the evening of April 2, 1892, twenty-nine were males and six were females. At this date they were in copulation. Eggs were laid from April 18th to 30th. I have frequently found females bearing well grown young in the small streams, and therefore do not think that the habit of burrowing is adopted as a protection to the young generation but rather to furnish a retreat during the dry summer months.

CAMBARUS ARGILLICOLA Faxon.

Cambarus argillicola Faxon, Proc. Amer. Acad. Arts and Sci., Vol. XX, pp. 115–116, 1884.

Cambarus argillicola Faxon, Mem. Mus. Comp. Zoöl., Vol. X, No. 4, p. 76, 1885.

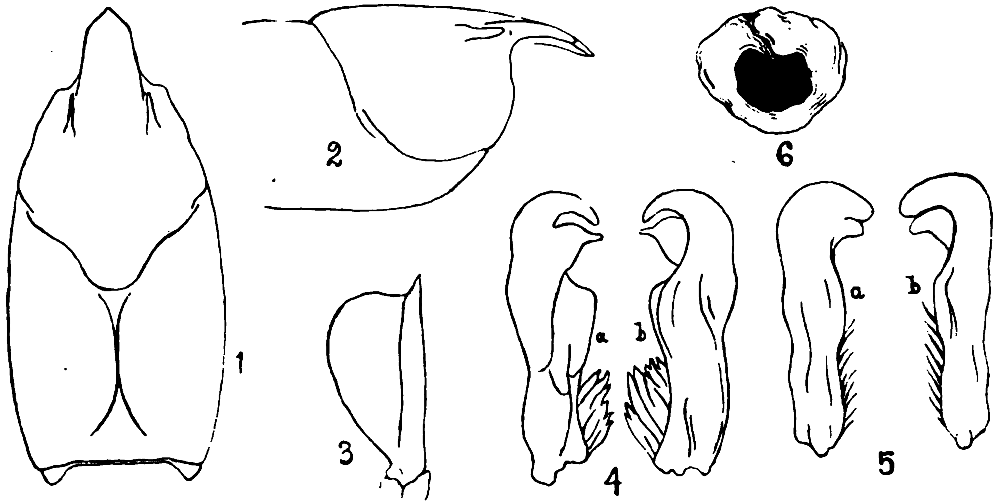


FIG. 8. *Cambarus argillicola.*—1 and 2, carapace from above and from the side; 3, antennal scale; 4, first abdominal appendages, male, F. I; 5, same, F. II; 6, annulus ventralis.

Male, Form I.—Rostrum short, broad, decurved, and well excavated, foveolate at base, edges raised, slightly converging toward the tip and then suddenly turning inward to form the triangular acumen, lateral teeth wanting. Postorbital ridges grooved externally and without spines. Carapace compressed, nearly smooth above, slightly granulate on the sides, and without lateral or branchiostegal spines, front border of carapace straight, no projecting angle below the eye. Cervical groove deep, sinuate, and broken on the sides. Areola obliterated in the middle, anterior triangular space very small, posterior space larger. Abdomen slender, about as long as the carapace, pleural angles rounded; proximal segment of telson bispinose on each side, distal segment rounded. Antennæ shorter than the body, scale small, shorter than the rostrum, broadest beyond the middle and truncate at the tip, terminal spine very small. Epistoma rounded or broadly triangular, with convex sides. Third maxillipeds hairy on inner and outer faces, the beard being long and abundant within and short and scant without. Chelæ large and strong; hand inflated and nearly smooth, inner border serrate, fingers flattened and thickly punctate. Upper surface of movable finger with prominent ridge or rib bordered by a row of depressions; this finger, also, is cut out at the base and does not meet its fellow except for about the distal half of its length. Outer finger shorter than inner, not incurved, and usually bearded at the base. Carpus strong, deeply furrowed above, a large spine on inner surface and another on the lower surface near the distal end. Meros with a few very small spines above, near the distal end, and two rows of small tooth-like spines beneath. Two last segments of second pair of legs hairy. Third pair of legs hooked. First abdominal appendages consisting of two falciform teeth, of nearly equal length, placed one above the other, lower tooth thick and strong, upper tooth, formed by outer part of the appendage, thin, spatulate, and corneous.

Male, Form II.—Similar, but with weaker chelæ, which are almost always bearded. Abdominal appendages thicker, and with short, blunt teeth

Female.—Similar. Annulus ventralis with anterior border depressed to a level with the thoracic sterna, irregularly oval, consisting of a circular swollen ridge surrounding a deep depression, broken posteriorly by a narrow fissure.

Measurements of male, Form I.—Length, 71; carapace, 36.5; abdomen, 34.5; rostrum, 7; tip of rostrum to cervical groove, 23. Breadth, carapace, 17; rostrum, 5; areola, 0; second abdominal segment, 14.

Indiana Localities.—Irvington, Marion county; Bloomington, Monroe county; Wheatland, Knox county; New Albany, Jefferson county.

Cambarus argillicola is a small species resembling and very closely related to *C. diogenes*. Like its relative, it is a burrower, and builds mud chimneys over its holes. I have taken females with young as early as April 2.

As to the probable extent of this species in our State, it would be possible to say only this much: Dr Faxon's description was written from specimen's taken in Detroit, Mich , and I have received from Prof. A. A. Wright specimens from Oberlin, Ohio; so it would appear that the localities given by no means represent its distribution.

CAMBARUS INDIANENSIS SP. NOV.

Cambarus affinis var. Faxon, Proc. U. S. Nat. Mus. XII, p. 628, 1890.

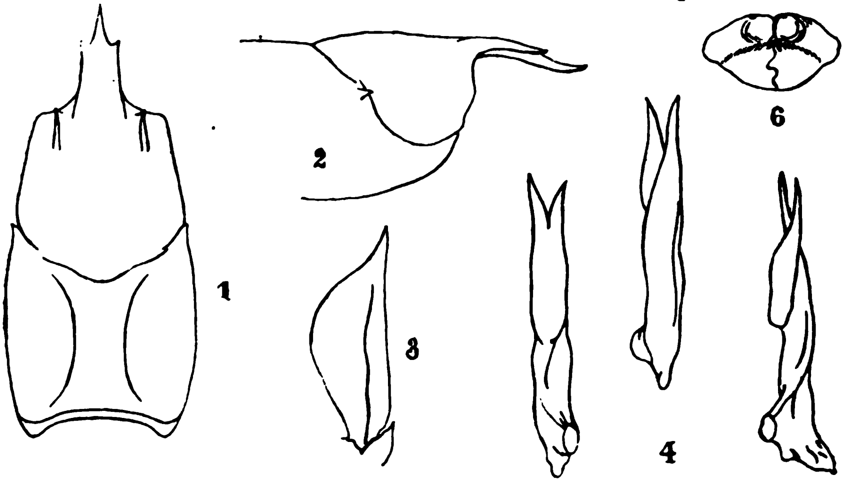


Fig. 9. *Cambarus indianensis.*—1 and 2, carapace from above and from the side; 3, antennal scale; 4, first abdominal appendage, male, F. I; 6, annulus ventralis.

Male, Form I.—Rostrum long, straight and well excavated, lateral spines acute and turned slightly outward. Acumen slender, sides concave, tip acute. Post-orbital ridges with a strong, acute spine. Carapace cylindrical, nearly smooth above, slightly punctate, sides slightly granulate, lateral spine prominent and acute, branchiostegal spine nearly obsolete. Cervical grove sinuate and broken on the sides. Areola wide. Abdomen a little shorter than the cephalothorax, pleural angles obtuse; telson tapering, rounded behind, proximal segment bispinose on each side. Eyes large and prominent. . Antennæ shorter than the body, scale large, as long as rostrum, widest about the middle and curving gradually to the acute, somewhat outwardly directed terminal spine, basal joint of antennæ with a small acute spine. Third maxillipeds hairy on inner face. Chelipeds rather slender, chelæ rounded and smooth, very lightly punctate; fingers rounded, inner finger sinuate, outer finger slightly bearded at base, tips of both fingers in-curved. Carpus nearly smooth above, with a small internal and a still smaller inferior spine. Meros with two small spines above at the distal end and three or four similar ones on the inferior margin. Two distal segments of the second, fourth and fifth pairs of legs hairy. Third pair of legs hooked. First pair of abdominal appendages of medium length, terminating in two nearly straight, slightly diverging rami of nearly equal length, the outer ramus being slightly thicker than the inner.

Male, Form II.—Not known.

Female.—Similar to male except that the fingers are shorter and the beard on the hands is somewhat denser. Annulus ventralis small, hardly raised above the level of the thoracic sterna, wider than long, anterior wall faintly bi-tuberculate, longitudinal fissure narrow, posterior wall poorly defined, median depression shallow.

Measurements of male, Form I.—Length, 45.5; carapace, 22.5; abdomen, 23; rostrum, 7; rostrum to cervical groove, 15.5. Breadth—carapace, 10.5; rostrum, 3; areola, 2; second abdominal segment, 9.

Indiana Localities.—Patoka River, Patoka, Gibson county; Huntingburg, Dubois county.

Concerning the habits of this species I have been able to ascertain nothing. It probably is a form which frequents open waters much after the fashion of its close relative *C. affinis*, of the East, of which Dr. Faxon was at first inclined to regard this a variety.

CAMBARUS SLOANII Bundy.

Cambarus sloanii Bundy, Bull. Ills. Mus. Nat. Hist., No. 1, p. 24, 1876.

Cambarus sloanii Faxon, Mem. Mus. Comp. Zoöl., X, No. 4, 1885.

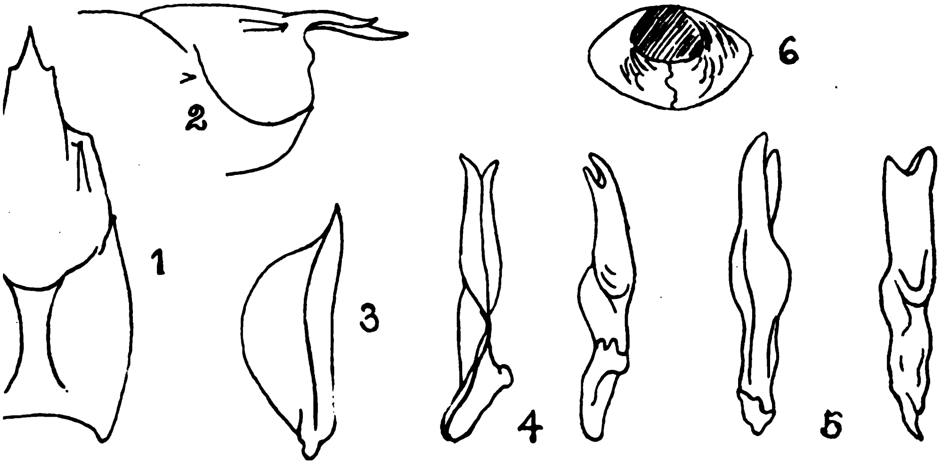


FIG. 10. *Cambarus sloanii.*—1 and 2, carapace from above and from the side; 3, antennal scale; 4. first abdominal appendage, male, F. I; 5, same, F. II; 6, annulus ventralis.

Male, Form I.—Rostrum long, wide, well excavated and with nearly parallel margins; lateral teeth usually prominent, but sometimes, in large individuals, almost obsolete; acumen long and slender. Postorbital ridges short, spine small or wanting. Carapace cylindrical, slightly flattened above, lightly granulate on the sides, lateral spine small but acute, front border of carapace notched just above the very small branchiostegal spine. Cervical groove very slightly or not at all sinuate, broken on the sides. Areola wide. Abdomen about as long as cephalothorax, pleural angles obtuse, basal segment of telson bispinose on each side, distal segment short and rounded. Antennæ slender, a little shorter than the body, scale a little longer than the rostrum, widest beyond the middle and curving gradually to the strong apical tooth. Epistoma triangular, notched in front and with raised convex margins. Third maxillipeds hairy on inner face. Chelæ short and thick, inner border with a double row of blunt teeth; outer finger furrowed above near the outer and inner margins, inner finger serrate on external (non-opposable) margin, opposable margins of both fingers beset with blunt teeth and touching only at their tips. Carpus with one large internal spine. Third pair of legs hooked. First pair of abdominal appendages thick, composed of two branches which are of nearly equal length and slightly twisted upon one another, free tips of these branches short, acute and horny, tip of outer branch turned outwards, tip of inner branch turned inwards; a large inwardly projecting knob at base of appendage.

Male, Form II.—Chelæ smaller, hooks on third pair of legs almost obsolete, first abdominal appendages thicker, free tips shorter and not horny, sometimes with an articulation near the base and without the large inwardly projecting knob.

Female.—Similar to male, Form II. Annulus ventralis oval, anterior border depressed, posterior border elevated and tuberculate, tubercle divided by a narrow longitudinal fissure.

Measurements of male, Form I.—Length, 55.5; carapace, 28; abdomen, 27.5; rostrum, 8; rostrum to cervical groove, 18.5; antennæ, 51. Breadth—carapace, 14; rostrum, 3.5; areola, 2; second abdominal segment, 11.5.

Indiana Localities.—New Albany, Floyd county; Madison, Jefferson county; Marengo, Crawford county.

This species is apparently quite abundant in southern Indiana, frequenting the muddy banks of running streams. Dr. Sloan, for whom the species was named, has made observations on its habits, as follows: "He commences on the bank of the stream, burrows below the bed, and has an opening two or more feet out in the stream, where he sits watching for anything that may turn up, with a safe retreat."

CAMBARUS PROPINQUUS Girard..

Cambarus propinquus Girard, Proc. Acad. Nat. Sci. Phila., VI., 88, 1852.

Cambarus propinquus Hagen, Ill. Cat. Mus. Comp. Zoöl., No. III., p. 67, 1870.

Cambarus propinquus Faxon, Mem. Mus. Comp. Zoöl., X. No. IV., p. 91, 1885.

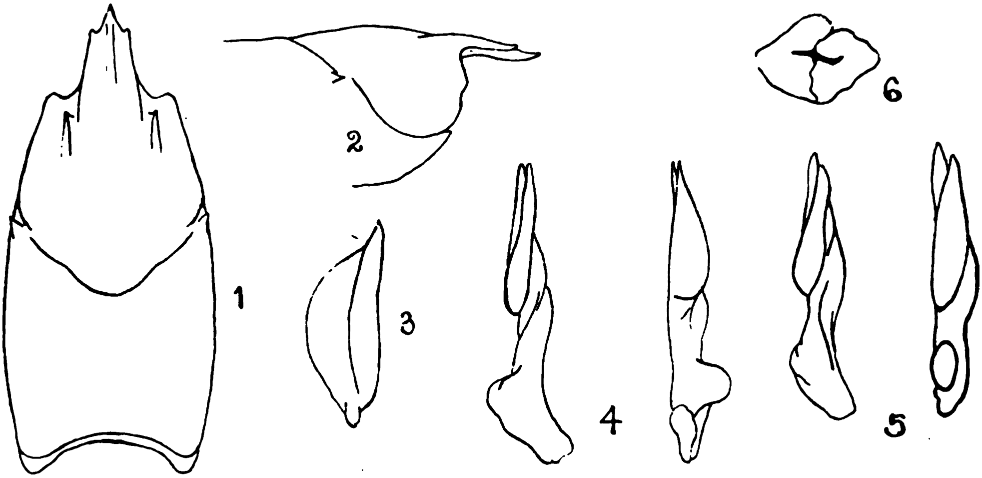


FIG. 11. *Cambarus propinquus.*—1 and 2, carapace from above and from the side; 3, antennal scale; 4, first abdominal appendages, male, F. I; 5, same, F. II; 6, annulus ventralis.

Male, Form I.—Rostrum long, narrow, well excavated, and with nearly parallel raised margins, acumen long, slender, and with concave sides, terminal spine acute, lateral teeth small. Just between the lateral teeth on the upper surface is a low longitudinal ridge. Post-orbital ridges short, grooved on the outer face, spine short and acute. Carapace cylindrical, smooth and punctate above, lightly granulate on the sides, lateral spines small. Cervical groove deep, hardly sinuate, broken on the sides, and ending just above the very minute branchiostegal spine. Areola broad and smooth. Abdomen strong, longer than carapace, pleural angles obtuse, telson tapering, proximal segment bispinose on each side, distal segment rounded behind. Antennæ stout, much shorter than the body, scale slightly longer than the rostrum, broadest near the middle and thence curving gradually to the acute terminal spine. Epistoma about as broad as long, sides convex and raised. Third pair of maxillipeds with inner face hairy. Chelæ rather short, rounded, slightly tuberculate on inner margin, nearly smooth above, movable finger sinuate, tips of fingers incurved, brown and horny, outer finger sometimes slightly bearded at base. Carpus with a short, shallow furrow above, and with one strong spine on inner surface and another at the distal end beneath. Meros with one or two spines on the upper surface at the distal end and with two spines on lower surface. Distal joints of all the smaller legs more or less hairy. Third pair of legs hooked. First pair of abdominal appendages short and twisted, reaching nearly to the base of the second pair of legs, free tips rather long, slender and acute, tip of internal branch somewhat spatulate.

Male, Form II.—Similar to Form I, but with weaker chelæ and less carinated rostrum. First pair of abdominal appendages shorter, the branches swollen, the free tips short and blunt.

Female.—With shorter chelipeds. Rostrum sometimes without median carina. Annulus ventralis ovoid, anterior margin bi-tuberculate, posterior margin with a single low, median tubercle crossed by a narrow sinuous fissure, median depression crescentic, narrow and deep.

Measurements of male, Form I.—Length, 44; carapace, 21.5; abdomen, 22.5; rostrum, 6; rostrum to cervical groove, 14; antennæ, 33. Breadth—carapace, 11; rostrum, 3; areola, 2; second abdominal segment, 9.5.

Indiana Localities.—Delphi, Carroll county; Elkhart River, Noble county; Indianapolis, Irvington, Millersville, Marion county; Michigan City, Laporte county; Lake Maxinkuckee and Twin Lakes, Marshall county; Turkey Lake, Kosciusko county; Waterloo (Indian Lake), DeKalb county; Turman Creek, Sullivan county; Lafayette, Tippecanoe county; Clear Creek, Monroe county; Switz City, Greene county; Brookville, Franklin county; Salt Creek, Brown county. This is probably the most abundant species in our State. It is usually found in large numbers in the smaller streams hiding under stones, concealed in short burrows along the banks, or resting quietly on the bottom. I have been unable to obtain collections from the eastern counties of the State where possibly this species runs into the variety *sanbornii* Fax, which is distinguished from the typical form by the non-carinated rostrum, less deeply bifid abdominal appendages, pubescent chelæ and an inferior median anterior spine on the carpus. This variety has been collected in Carter county, Kentucky, and at Oberlin, Ohio, where, I am told by Mr. Lewis McCormick, it is, by far the most abundant species.

CAMBARUS VIRILIS Hagen.

Cambarus virilis Hagen, Ill. Cat. Mus. Comp. Zoöl., No. III, p. 63, 1870.

Cambarus virilis Faxon, Mem. Mus. Comp. Zoöl., X, No. 4, p. 96, 1885.

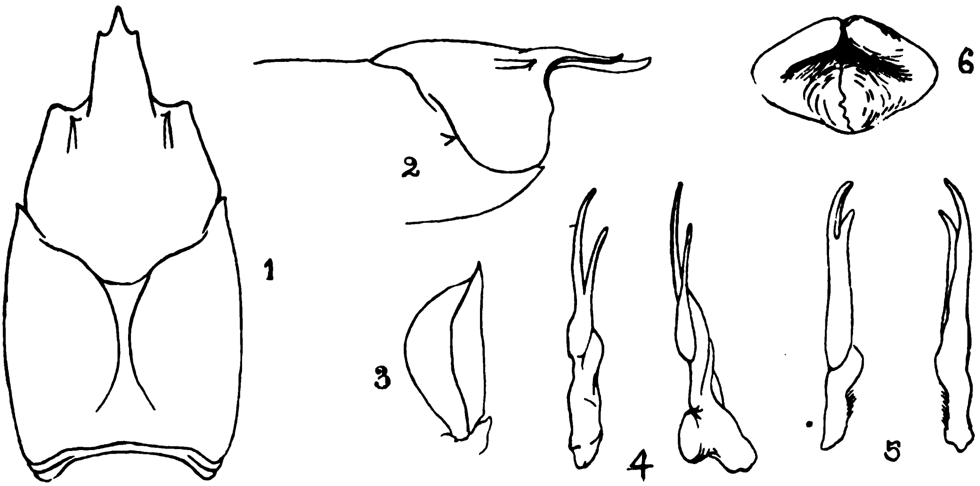


FIG. 12. *Cambarus virilis.* 1 and 2, carapace from above and from the side; 3, antennal scale; 4, first abdominal appendages, male, F. I; 5, same, F. II; 6, annulus ventralis.

Male, Form I.—Rostrum broad, long, well-excavated, and with raised converging margins; lateral teeth prominent and acute; acumen slender, sides concave, terminal spine sharp. Post-orbital ridges grooved on outer face, slightly swollen behind, and with an acute spine in front. Carapace cylindrical, smooth and thickly punctated above, granulate on the sides; lateral spine well developed, branchiostegal spine small; cervical groove deep, sinuate, broken on the sides; areola of moderate width, narrowest near the anterior end, strongly converging behind. Abdomen broad, as long as the cephalothorax; telson tapering; proximal segment bispinose on each side; distal segment short; posterior margin variable, rounded, straight or sinuate. Antennæ shorter than the body, scale as long as the rostrum, internal border rounded, widest about the middle; apical spine small. Third pair of maxillipeds hairy on the inner face. Chelipeds short and strong; chelæ broad and rather flattened; inner border of the hand and the movable finger biseriately tuberculate; both fingers strongly punctate above and with a pretty well defined smooth ridge; inner margin of outer finger straight, provided with strong tubercles and bearded; movable finger notched at the base. Carpus longer than wide, not very deeply furrowed above, with a strong spine on the inner surface and two slightly smaller beneath. Meros with two small spines above near the distal end and a double row of acute spines on the lower border. Third pair of legs hooked. First pair of abdominal appendages very long, reaching to the base of the chelipeds, deeply bifid, the branches slender and slightly curved backward; the outer branch the longer, inner branch spatulate at the tip, which may be acute or blunt.

Male, Form II.—Similar, but with smaller and weaker chelæ; first pair of abdominal appendages usually articulated at the base, apex divided for but a short distance, branches cylindrical, blunt and nearly straight.

Female.—Similar. Annulus ventralis large, oval; anterior wall narrow, broken by the longitudinal fissure; posterior wall thick, elevated, crossed by a narrow, sinuous longitudinal fissure; median depression transverse, deep.

Measurements of male, Form I.—Length, 68; carapace, 33; abdomen, 35; rostrum, 8; rostrum to cervical groove, 21. Breadth—carapace, 16 5; rostrum, 5; areola, 1; second abdominal segment, 14.5.

Indiana Localities.—Elkhart River, Goshen, Elkhart county; Twin Lakes, Lima, Lagrange county; Rome City, Noble county; Lake Michigan, Michigan City, Laporte county; Long Lake, Noble county; Turkey Lake, Kosciusko county; Shelby, Lake county.

This species seems to be confined, in its distribution in Indiana, to the lakes and streams of the northern portion of the State. Here it is extremely abundant and attains a large size. I have seen specimens 120 mm in length, and Professor W. F. Bundy records a length of 165 mm. In the lake regions of Wisconsin and Minnesota this species is said to be used extensively as food.

Cambarus immunis Hagen.

Cambarus immunis Hagen, Ill. Cat. Mus. Comp. Zoöl , No. III, p. 71, 1870.

Cambarus immunis Faxon, Mem. Mus. Comp. Zoöl., X No 4, p. 99, 1885.

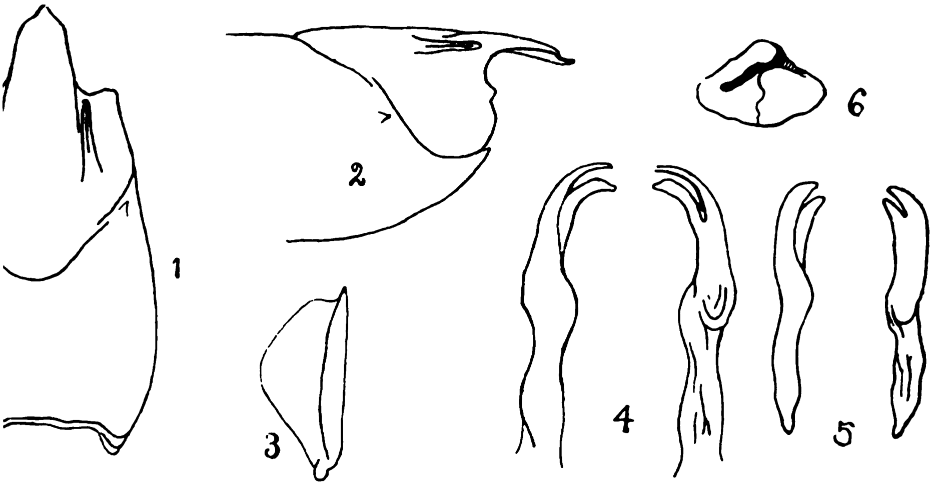


FIG. 13. *Cambarus immunis*.—1 and 2, carapace from above and from the side; 3, antennal scale; 4, first abdominal appendages, male, F. I, 5, same, F. II; 6, annulus ventralis.

Male, Form I.—Rostrum broad, long, well excavated, decurved, and with raised converging sides, usually with indications of a foveola at base; lateral teeth absent, acumen triangular with concave sides. Post-orbital ridges grooved on their outer faces, and without spines. Carapace smooth above, densely punctate, granulate on the sides, lateral spine present but very small, branchiostegal spine very small or wanting; cervical groove slightly sinuate, broken on the sides, areola narrow in the middle, anterior triangular space small, posterior space very large. Abdomen wide, longer than the body, pleural angles rounded; proximal segment of telson bispinose on each side, posterior border of distal segment slightly concave. Antennæ slender, shorter than the body, scale considerably longer than the rostrum, widest at the middle, truncate at the end, apical spine small. Epistoma triangular, notched in front, and with a minute median tooth, sides convex and raised. Third maxillipeds hairy on both inner and outer faces. Chelæ of medium size, variable in form, usually rather slender; internal border of hand and movable finger serrate, upper surface of both fingers with a smooth rib bordered on each side by a line of depressions, outer finger usually bearded at base on inner border, movable finger usually excised at base inside and provided with a prominent tooth. Carpus deeply furrowed above, provided with several strong spines along the inner and lower aspects of the distal border. Meros with two weak spines above and a double row of stronger ones beneath. Second pair of legs with dense tufts of hair on the inner side near their extremities. Third pair of legs hooked. First pair of abdominal appendages reaching to base of second pair of legs, falciform, twisted, and deeply bifid, external branch the longer, its tip slender and acute, tip of inner branch flattened and spatulate; on a level with the base of the inner branch there is, on the outer side, a projecting shoulder.

Male, Form II.—Chelæ smaller and weaker; First abdominal appendages slender and less deeply divided, branches thick, blunt and less curved. Second pair of legs less hairy.

Female.—Similar to male, Form II; annulus ventralis ovoid, wider than long, depression lying far to one side, irregular (sigmoid) in form, walls raised and inflated, posterior wall crossed by a narrow fissure.

Measurements of male, Form I.—Length, 63; carapace, 30; abdomen, 33; rostrum, 7; rostrum to cervical groove, 19.5; antennæ, 51. Breadth, carapace, 16; rostrum, 4.5; areola, 1; second abdominal somite, 14 5.

Indiana Localities: White River, Fall Creek, Irvington, Marion County; Long Lake, Kendallville, Noble county; Wabash River, Posey county; Twin Lakes, Marshall county.

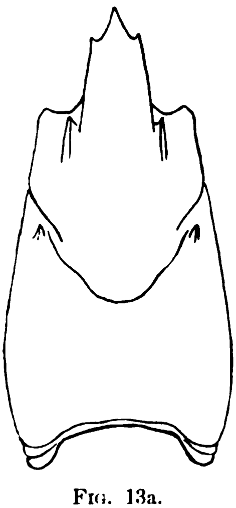


FIG. 13a.
Carapace of *Cambarus immunis spinirostris.*

This species is a mud lover, being found in great numbers in muddy ponds in the early spring. I have always found them in the greatest abundance in ponds which become perfectly dry during the summer months, but where the crawfish go during this time I have never been able to ascertain. Doubtless great numbers of them are eaten by birds and other animals, and great numbers of them perish, yet by the next spring they are as abundant as ever, and of about the same size.

From Prof. J. T. Scovell, of Terre Haute, I have received specimens which clearly belong to *Cambarus immunis spinirostris* Faxon, which differs from the typical form in the following characters: The rostrum with small but acute lateral teeth; post-orbital spines developed; lateral spines strong and acute; areola wider and slightly shorter in proportion to the anterior segment of the carapace; abdomen longer in proportion to carapace; antennæ longer than the body. In the second-form males the tufts of hair on the second pair of legs are not at all developed, but in a large male of Form I they are very conspicuous. The first abdominal appendages of the males of both forms and the annulus ventralis of the female are like those parts in the typical form.

Indiana Locality—Streams of Vigo county.

CAMBARUS RUSTICUS Girard.

Cambarus rusticus Girard, Proc. Acad. Nat. Sci. Phila., VI, p. 88, 1852.

Cambarus rusticus Hagen, Ill. Cat. Mus. Comp. Zoöl., No. III, p. 71, 1870.

Cambarus rusticus Faxon, Mem. Mus Comp. Zoöl., X, No. 4, p. 108, 1885.

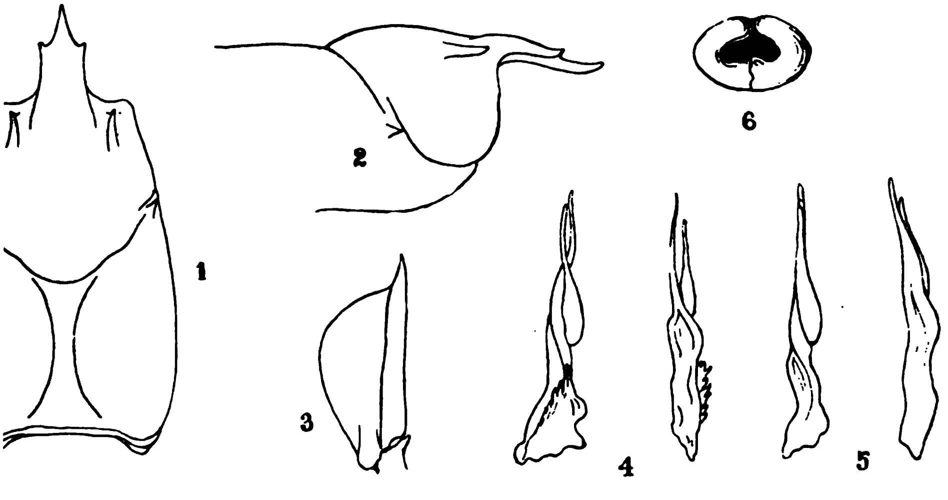


Fig. 14. *Cambarus rusticus.*—1 and 2, carapace from above and from the side; 3, antennal scale; 4, first abdominal appendages male, F. I; 5, same, F. II; 6, annulus ventralis.

Male, Form I.—Rostrum long, narrow, concave on sides and deeply excavated, margins raised, divergent at the base; acumen slender, terminal spine acute, upturned, brown and horny; lateral spines acute, upturned, brown and horny. Post-orbital ridges short, grooved on outer face, spines short. Carapace flattened above, smooth and punctate, granulate on the sides; lateral spine small, branchiostegal spine wanting; cervical groove deep, sinuate, broken on the sides; areola wide. Abdomen strong, as long as cephalothorax, pleural angles obtuse, telson wide, basal segment bispinose on each side, distal segment rounded behind. Antennæ about as long as the body, scale as long as rostrum, widest beyond the middle. Epistoma triangular, sides convex, apex blunt. Third pair of maxillipeds hairy on inner face. Chelæ large and strong, inner border of hand and movable finger tuberculate, fingers and hand ornamented with lines of dots, fingers gaping at base, outer finger sometimes slightly bearded, movable finger sinuate, the tip incurved. Carpus strong, furrow on upper surface shallow, spine on inner surface small but strong, usually two strong spines beneath. Meros with two small spines above and two stronger, and sometimes several smaller ones beneath. Third pair of legs hooked. First pair of abdominal appendages long, twisted, deeply split and with slender branches; inner branch shorter than outer and not as slender.

Male, Form II.—Similar; first pair of abdominal appendages thicker, split for only a short distance and not slender and acute.

Female.—Very similar; annulus ventralis oval, bi-tuberculate in front, median depression deep, posterior wall raised into a tubercle which is divided by a very narrow sinuous fissure.

Measurements of male, Form I.—Length, 67; carapace, 34; abdomen, 33; rostrum, 9; rostrum to cervical groove, 22.5. Breadth, carapace, 18; rostrum, 4.5; areola, 2.5; second abdominal segment, 15.

Indiana Localities.—Waterloo, Dekalb county; Brookville, Franklin county; White River, and Irvington, Marion county; Ohio River, Jefferson county.

This species has very much the same habits as *C. propinquus* and the two are often found in company. *C. rusticus*, however, is much less common. It may be instantly recognized by the concave sides of the rostrum.

CAMBARUS PUTNAMI Faxon.

Cambarus putnami Faxon, Proc. Amer. Acad. Arts and Sci., XX, p. 131, 1884.

Cambarus putnami Faxon, Mem. Mus. Comp. Zoöl., X, No. 4, p. 118, 1885.

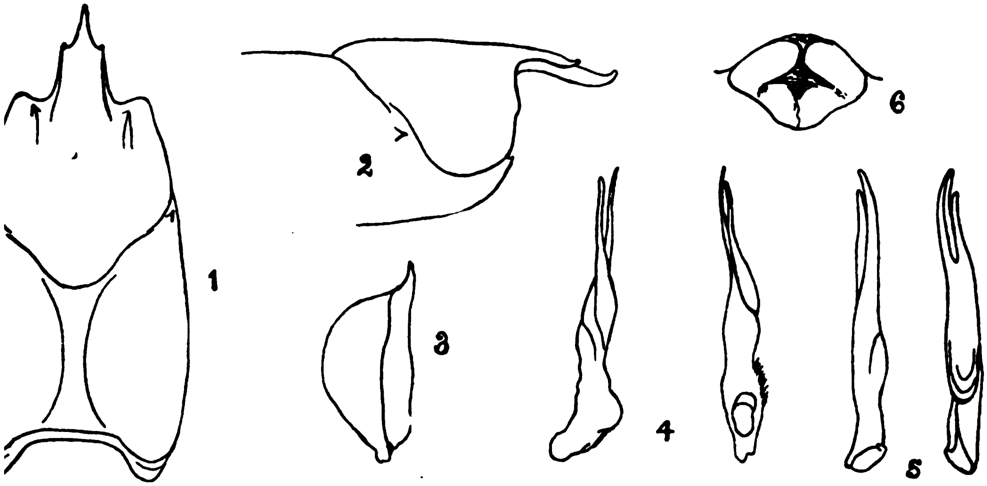


FIG. 15. *Cambarus putnami*.—1 and 2, carapace from above and from the side; 3, antennal scale; 4, first abdominal appendage, male, F. I; 5, same, F. II; 6, annulus ventralis.

Male, Form I.—Rostrum broad, well excavated, margins raised, nearly parallel in front, diverging behind; acumen long, slender, with concave sides, and terminated by an upturned, dark brown, horny spine; lateral spines strong, dark brown, horny. Post-orbital ridges short, grooved on outer face, swollen behind, terminated in front by a short, acute spine. Carapace somewhat flattened above, everywhere punctate, smooth or very lightly granulate on the sides, lateral spine small, branchiostegal spine minute or wanting; cervical groove deep, broad, broken on the sides; areola of moderate width, punctate. Abdomen as long as the thorax, pleura punctate, angles obtuse; sides of telson sinuous, proximal segment bispinose on each side, distal segment rounded behind. Antennæ slender, about as long as the body. Epistoma notched in front, sides convex and raised. Third pair of maxillipeds lightly bearded on the inner face. Chelipeds large and strong, chelæ large, external border convex, outer finger slender, inner finger sinuate, fingers gaping widely at the base, they and the hand thickly and deeply punctate above and below. Carpus strong, broadly furrowed above, with a strong spine on the inner face and two blunt spines on the lower surface. Meros with two small spines above, near the distal end, and one or two large blunt ones beneath. Third pair of legs hooked. First pair of abdominal appendages long and twisted, reaching to the base of the second pair of legs, deeply bifid, the branches slender; the outer branch is curved around to the inside and is the longer, the inner branch is curved toward the middle line, the tip is flattened and somewhat spatulate, base of the appendage with a projecting knob on the inner side.

Male, Form II.—Chelæ smaller; first pair of abdominal appendages articulated near the base, bifid only half as far as in form I, branches thicker, base without a projecting angle.

Female.—Chelæ shorter and wider, outer finger bearded within at the base. Annulus ventralis large, anterior wall bi-tuberculate, posterior wall raised and crossed by a narrow fissure, central depression transverse, deep.

Measurements of male, Form I.—Length, 102; carapace, 50; abdomen, 52; rostrum, 13; rostrum to cervical groove, 32. Breadth, of carapace, 27; rostrum, 6.5; areola, 2; second abdominal segment, 22.

Indiana Localities.—Bradford, Harrison county (?); Brookville, Franklin county.

In the Indiana State Museum there are two very large specimens of this crawfish for which no locality is given; it is probable, however, that they are from our State. In my own collection there is a small second-form male, collected between Paoli, Orange county, and Wyandotte Cave, which I refer with some doubt to this species.

LIST OF PAPERS TREATING OF THE SPECIES OF CRAWFISHES FOUND IN INDIANA.

1798. Fabricius. Supp. Entomol. Systemat.

1844. Tellkampf. Mueller's Archiv., p 383.

1846. Erichson. Wiegmann's Archiv. Jahrg., XII, 86 and 375.

1854. Charles Girard. Proc. Phil. Acad., VI, p. 87. "A Revision of the North American Astaci, with Observations on their Habits and Geographical Distribution."

1870. Herman A. Hagen. "A Monograph of the North American Astacidæ." Ill. Cat. Mus. Comp. Zoöl., No. III.

1872. E. D. Cope. "Report on the Wyandotte Cave and Its Fauna," pp. 157–182, 3d and 4th Ann. Rept. Geolog. Survey Ind.

1873. A. S. Packard "On the Cave Fauna of Indiana," 5th Ann. Rept. Peabody Acad. Sci., Salem, pp. 93–97.

1874. S. I. Smith. "Crustacea of the Fresh Waters of the U. S.," U. S. Fish Comm. Rept., 1872–1873.

1876. S. A. Forbes. List of Illinois Crustacea, etc. Bull. Ill. Mus. Nat. Hist., No. 1, pp. 3–25.

1877. W. F. Bundy. "The Cambari of Northern Indiana." Proc. Acad. Nat. Sci., Phila, 1877, pp. 171–174.

1885. Walter Faxon. A Revision of the Astacidæ. Mem. Mus. Comp. Zoöl., Vol. X, No. 4.

1890. Walter Faxon. "Notes on North American Crayfishes." Proc. U. S. Nat. Mus., Vol. XII, pp. 619–634.

1891. W. P. Hay. "The Crustacea of Indiana." Proc. Ind. Acad. Sci., 1891, pp. 147–150.

1893. W. P. Hay. "Observations on the Blind Crayfishes of Indiana, with a Description of a New Sub-species; *Cambarus pellucidus testii*." Proc. U. S. Nat. Mus., Vol. XVI, pp. 283–286.

GENERAL INDEX.

PAGE.

Absorption Test for Paving Brick 149
Acknowledgments . . . . vi, 46, 187, 368, 369, 475
Adams County—Wells completed in, in 1895 472
"Air Line" Railway 107, 111, 115, 119, 121, 122, 127, 312
Albany Slip Clay 47, 56
Allophane 105
Alluvial Clays 33, 35, 75
 Analysis of 76
 Comparative Value of for Paving Material 137
American Cannel Coal Company 126, 131
Analyses of—Natural Gas 376, 401
 Sandstone 322
 Shales 129
 Under-Clays 133
Andrews, John—Clays on Land of 83
Annapolis Pottery 49
Archimedes 333
Arenaceous Shales 45, 76
Argillaceous Shales 45
Assistants of State Geologist 4
Astacinæ 476
Astacus 476
Atmosphere—An Active Agent in the Formation of Clays 30
Attica—Clays in Vicinity of 59
 Sandstones in Vicinity of 286, 300
Auger Brick Machines—Relative Value of 141

Baltimore & Ohio Southwestern Railway 97, 100, 101, 104, 336
Bernhart's Quarry 300
Bicknell, Knox County—Clays in Vicinity of 96
Bituminous Shales 44
Blackford County—Oil wells completed in, in 1895 472
Blast Furnaces—Disappearance of, in Indiana 20
Blende, Zinc—Occurrence of, in Indiana 20
Block Coal 8, 78, 83, 84
Bloomingdale—Clays in Vicinity of 47
Bockting Bros.—Clay Deposits of 107
Boonville—Clays in Vicinity of 119
Braxton Whetstone Quarry 348
Brazil Block Coal Company 80, 422, 433, 438
Brazil Brick and Pipe Company 78, 167
Brazil—Clays in Vicinity of 77
 Sandstones in Vicinity of 309
Briar Block Coal Company 80, 434

PAGE.
Brick, Dry-pressed—Making of . . . 175
Statistics of . . . 177
Hollow—Making of . . . 165
Statistics of . . . 167
Ordinary—Making of . . . 178
Statistics of . . . 179
Paving—Burning of . . . 143
Choice of Clays for . . . 136
Cost of Making . . . 149
Cost of Plant for Making . . . 147
Drying . . . 142
Laminations in, Cause of . . . 142
Locating Plant for . . . 138
Making of . . . 141
Preparation of Clays for . . . 139
Quantity of Clay Necessary for . . . 138
Standard Composition of Clays Suitable for . . . 54
Statistics of Indiana Factories . . . 148
Testing of Clays for . . . 136
Testing of . . . 149
Use of for Streets in Indiana . . . 156
Broadhurst's Mine, Vigo County—Section of . . . 72
Building Stone . . . 16
Burns and Hancock—Clays on Land of . . . 67

Cable & Kaufmann's Mine—Clays at . . . 98
Mineral Water Near . . . 98
Calcareous Shales . . . 46
Calcite . . . 67
Cambarus—Generic Characters . . . 476
Known Species of . . . 477
Specific Characters . . . 477
Cambarus—*Argillicola* . . . 492
Bartonnii . . . 487
Blandingii acutus . . . 481
Diogenes . . . 489
Gracilis . . . 486
Immunis . . . 501
Immunis spinirostris . . . 502
Indianensis . . . 494
Pellucidus . . . 482
Pellucidus testii . . . 484
Propinquus . . . 497
Putnami . . . 504
Rusticus . . . 503
Sloanii . . . 495
Virilis . . . 499
Cannelton—Clays in Vicinity of . . . 124
Sandstones in Vicinity of . . . 314
Cannelton Stoneware Company . . . 125
Carbon Dioxide—An Agent in the Formation of Clays . . . 30
Constituent of Natural Gas . . . 378
Carbon Monoxide . . . 378
Caseyville—Clays in Vicinity of . . . 57
Cayuga Pressed Brick Co—Clays of . . . 70
Sandstone Quarry of . . . 276
Chemical Analyses of Clays—Tables of . . . 129, 183
Value of . . . 136
Natural gas . . . 376, 401
Sandstones . . . 322
Chicago & Eastern Illinois Railway . . . 65, 67, 306, 308
Chicago Sewer Pipe Co. . . . 79
Cincinnati Arch . . . 384

PAGE.

Clark, A. D.—Stoneware factory of ... 124
Clays—Action of acids on ... 27
  Alluvial ... 33, 35, 76, 137
  Classification of ... 35
  Combined Water of ... 26
  Definition of ... 24
  Drift Clays ... 33, 34, 82
  Effects of Heat on ... 28
  High-Grade ... 35
  Impurities of ... 36
  Infusibility of ... 27
  Insolubility of ... 27
  Low-Grade ... 35
  Origin of ... 28
  Plasticity of ... 26
  Properties of ... 26
  Report on ... 23
  Residual ... 31, 35
  Screens for ... 140
  Sedimentary ... 32, 35
  Uses of ... 24
Clay City—Clays in Vicinity of ... 80
Clay County—Clays of ... 77
  Report on Mines of ... 433
Clay Products—Indestructibility of ... 24
  Value of, Used Annually in Indiana ... 24
  Value of, Made Annually in Indiana ... 40
Clay-Working Industries—Beginning of ... 23
  Growth of ... 19, 40, 134
"Clay-Worker"—Quoted ... 137, 144
Clinton—Clays in Vicinity of ... 65
  Coal Bore Near, Record of ... 66
Clinton Paving and Building Brick Company ... 65, 147, 148
Cloverland—Clays in Vicinity of ... 82
Coal—Amount Mined in Indiana in 1895 ... 10, 414, 425
  Area Underlain by, in Indiana ... 8
  Area—Counties Embraced in ... 42
  Available Amount Increased by Development of Clay Industries ... 19
  Bituminous—Analyses of ... 10, 114
    Area Underlain with ... 10
    Specific Gravity of ... 10
    Steam Value of ... 10
  Block—Analyses of ... 8
    Main Area of ... 9
    Purity of ... 9
    Specific Gravity of ... 9
    Steam Value of ... 9
    Value of for Burning Clay Products ... 78, 173
Coal—Energy Stored in ... 10
  Lancaster Block ... 84
  Origin of ... 42
  Production of Yearly from 1879 to 1895 ... 418
    By Counties in 1895 ... 418, 425
    By Mines in 1895 ... 426
    By Months in 1895 ... 419, 425
  Reports of Geological Survey Dealing with ... 10
  Strata—Typical Sections Through ... 43
Coal City—Clays in Vicinity of ... 84
Coal Creek Basin—Sandstones of ... 269
Coke Oven Hollow—Clays of ... 49
Collett, Prof. John ... 41, 86, 96, 324
Cone in Cone ... 82
Copper—Occurrence of, in Indiana ... 20

	PAGE.
Copperas	38
Covington—Clays in Vicinity of	63
Cox, Prof. E. T	11, 41, 72, 77, 104, 324, 337
Crawfishes—Bibliography of	507
Food of	477
Habits of	477
Key to Species Found in Indiana	478
Report on	475
Value as Scavengers	21
Crown Pottery Company, Evansville, Ind	173
Croy's Creek—Outcrops of Sandstone Along	215
Cubberly, Prof. E. P	384
Daviess County—Clays of	97
Report on Mines of	442
Dee Sewer-Pipe Company	56, 58, 167
Dixon, Solomon—Clay on Land of	56
Dover Hill—Kaolin in Vicinity of	102
Drain Tile—Manufacture of	178
Statistics of	179
Drift Clays	33, 82
Drift—Thickness of, in Indiana	388
Drypans—Description of	140
Dry-pressed Brick—Making of	175
Factory Statistics of	177
Dubois County—Area of	106
Clays of	106
Grindstone Rocks of	361
Sandstones of	212, 312
Edwardsport—Clays in Vicinity of	96
Eel River Basin—Sandstones of	213
Element—Definition of	25
Elrod, Dr. M. N	337
Energy—Conservation and Correlation of	6
Forms of	6
Stored by Plants	7
Sun, the Source of	6
Evansville—Clays in Vicinity of	116, 131
Evansville Pressed Brick Company	116, 148, 177
Evansville & Indianapolis Railway	74, 82, 83, 111
Evansville & Terre Haute Railway	91, 93, 114
Evans Quarry	231
Excelsior Clay Works	79, 167
Farnsworth—Clays in Vicinity of	92
Feldspar—Composition of	30
Constituent of Granite	29
Source of Kaolin	30
Origin of Kaolin from	30
Ferrous Oxide	37
Ferric Oxide	37, 109
Fire-Clay—Absence of Fluxes in	44
Characteristics of	33, 44
Comparative Value of for Paving Brick	137
Origin of	44
Statistics of Factories	170
Value of	57, 81, 122
Fire-damp—Mines Generating	430
Fire Kindlers—Made from Clay	169
Fisher, Robert	10, 11
Report of as State Mine Inspector	412

PAGE.
Fluxes of Clays—Definition 27
List of 27
Per Cent. of Admissible 39
Fountain County—Clays of 58
Report on Mines of 441
Sandstones of 212, 269
Freedom, Owen County—Clays in Vicinity of 85
French Lick Region—Whetstone Rocks of 348
Fuels—Definition of 5
Energy Stored in 6

Galloway, George—Clays on Land of 59
Gannister Rock 59
Gardner, Dr. J.—Kaolin on Land of 103
Gas, Natural—Area of Indiana Found in 13, 386
Companies, List of 405
Initial Pressure, Average 13, 391
Origin of 13, 380
Report of State Supervisor of 369
Supply of, Limited 13
Gasoline—Cause of Accidents 462
Need of Law for Inspection of 463
Geodes 115, 197, 335
Gibson County—Clays of 113
Glacier—As an Agent in the Distribution of Clays 34
Glass Factories in Indiana 390
Glass Pots—From Clay 168
Glass Rock 367
Gold—Occurrence of in Indiana 20
Gosport—Clays in Vicinity of 86, 175
Granite—Composition of 29
Origin of Clays from 30
Grant County—Oil-Wells Completed in, in 1895 472
Greene County—Clays of 87
Report on Mines of 443
Sandstones of 212, 310
Greenhill—Sandstones of 204, 303
Grindstone Rocks—Distribution of 357, 359
Manufacture of 358
Gypsum 81

Hall, C. F.—Report of State Supervisor of Oil Inspection 467
Hard-pan 33, 82
Haworth, Prof. Erasmus 105
Hay, W. P 21
Paper on Crawfishes by 475
Haynes, Elwood—Paper by 399
Heat—A Form of Energy 6
Stored in Fuels 6
Stored by Plants 7
Sun, the Source of 6
Helfrich, Adam—Clays on Land of 118
Hill, Robert F.—Quoted 24, 41
Hillsboro Pressed Brick Company 60, 177
Hillsboro—Sandstones in Vicinity of 271
Hillsdale—Clays in Vicinity of 51, 67
Hillsdale Fire Brick and Tile Company 69, 170
Hincho, B.—Quoted 123
Hindostan Whetstone 336
Beds of 347
Paleontology of 353
Hobson, Milton—Clay on Land of 47

PAGE.
Hollow Building Brick—Making of. . . . 165
Hopkins, T. C. . . . 17, 333, 368
Report of, on Sandstones 186
Hornblende 31
Huntingburg—Clays in Vicinity of 107
Huntingburg Pressed Brick Company 108, 168, 177
Huntington County—Oil Wells Completed in, in 1895 473
Hyatt, Jas. F.—Clays on Land of 84
Hyde, N. J.—Report of State Supervisor of Oil Inspection 461
Hydrocarbons of Natural Gas 402
Hydrogen Sulphide 379

Igneous Rocks 29
Indian Springs, Martin County—Kaolin Deposit Near 113
Indiana Clays—Classification of 35
Indiana—Comparative Area of 14
Gas field 386
Mines 20
Natural Resources of 5
Production of Petroleum in 12
Whetstones—Relative Value of 343
Indianaite 106
Indiana, Decatur & Western Railway 51, 52, 65, 67, 68, 318
Indiana & Illinois Coal Railway 51, 56, 60, 79, 231, 255, 283, 285, 300
Indiana & Illinois Southern Railway 91
Indianapolis & Vincennes Railway 83, 85, 86, 87, 96
Indiana Paving Brick Company 55, 66, 79, 148
Indiana Pottery Company 123, 174
Iron Carbonate 37
Ores in Indiana 20
Oxides 37, 71, 109
Sulphide 37
Sulphate 37
Island Coal Company 89

Jackson Hill Coal Company—Clays at Mines of 93
Jasper—Clays in Vicinity of 107
Sandstone in Vicinity of 313
Jay County—Oil Wells Completed in, in 1895 473
Johnson & Chenoworth—Kaolin Bank on Land of 101
Judson—Sandstones in Vicinity of 250, 252
Jug Rock 334

Kaolin—Definition of 25
Chemical Composition of 25
Crystalline Structure of 26
Occurrence of in Greene County 88
Lawrence County 103
Martin County 101
Owen County 86
Origin of from Feldspar 30
Kaskaskia Limestone 332
Sandstone 332
Kindle, E. M 18
Report of on Grindstone and Whetstone Rocks 329
Knobstone Shales 86, 175
Knox County—Clays of 94
Report on Mines of 444

Landers, Frank—Clays on Land of 80
Lawrence County, Kaolin 31, 41, 103, 109
Leach, J. C 13
Report of as State Supervisor of Natural Gas 380

PAGE.
Lead ore—Occurrence of in Indiana 20
Lepidodendra 349, 350
Lepidodendron clypeatum. 355
Lepidodendron veltheiamum 355
restitum 355
Lime—As an Impurity of Clays 38
Limestones—Crystalline 16, 367
Magnesian 17
Oölitic 16, 83
Trenton 387
Limonite—Occurrence of in Indiana 20
Occurrence of in Whetstone Rocks 339
Lincoln City—Clays in Vicinity of 121, 131
Linton—Clays in Vicinity of 88
Loogootee—Clays in Vicinity of 101
Lost River 330
Louisville, New Albany & Chicago Railway 83, 86, 311, 358
Ludowici Tile Company 54

McCune, S. L.—Clays on Land of 53, 131
McIndoo, John—Clays on Land of 85
Magnesia—An Impurity of Clays 38
Mansfield Sandstone—Adaptability 211
Composition 205, 206
Distribution 211, 232, 333, 365
Durability 208
Fire Tests of 207
Geologic Position of 200
Mineralogical Composition 206
Name—Why Adopted 199
Grains—Size of 204
Strength of 206
Structure 203
Texture 203
Varieties 200
Marble—Indiana 16, 367
Marion Brick Company 51
Marls 20
Marsh Gas 378
Marshall, Miles—Clays on Land of 62
Martin County—Clays of 100
Grindstone Rocks of 361
Matter—Definition 6
Indestructibility—Law of 6
Mecca—Clays in Vicinity of 53, 131
Coal in Vicinity of 55
Mica—Constituent of Granite 29
Impurity of Clay 31
Mill Creek—Outcrops of Sandstone on 218
Mine Accidents in 1895—Causes of 459
Fatal—List of 452
Minor—List of 456
Serious—List of 453
Mine Bosses—List of 419
Mine Inspector—Report of 412
Mining Machinery—Use of in Indiana 429
Miner's Oil—Impure Quality of 431
Ohio Law Concerning 431
Mine Operators—List of 422
Modelling Clay 63
Monarch Sewer Pipe Company 77, 167
Montezuma—Clays in Vicinity of 50, 67
Montezuma Fire Brick and Tile Company 69, 170

PAGE.
Montezuma Fire-Clay—Amount of Free Silica in 28
Analysis of. 133, 169
Description of 68, 169
Montgomery—Clays in Vicinity of 99
Museum, The State—Need of Cases for 22
Work Done in 21

Natural Gas—Chemical Composition 376, 401
Condition of Field in 1895 391
Fuel Value 379
Future of in Indiana. 396
History 373
Illuminant—As an 395
Indiana Field—Extent of 386
List of Companies 405
Origin and Accumulation 380
Pressure, and Measurements of 385
Report of State Supervisor of 369
Rock Pressure in December, 1895 391
Utilization of 399
Value of Consumed in United States 375
Waste of 394
Nebeker, Hon. E. H.—Clays on Land of 63
Neuropteris biformis Lx 354
smithsii Lx 354
Newburgh—Clays in Vicinity of 120
Northwestern Terra Cotta Company 54
Norton's Creek—Clays on 66

Oakland City—Clays in Vicinity of. 116
Office Work of Geologist. 22
Ohio—Clay Industries of 40, 135
Oil Inspection—Report of Supervisor for 1894 461
Report of Supervisor for 1895 467
Statistics of for Indiana in 1894. 463
Statistics of for Indiana in 1895. 469
Oil Inspectors, Deputy—List of 468
Oil, Miners'—Impure Quality of 431
Olefiant Gas 378
Orange County—Grindstone Rocks of. 359
Sandstones of 212, 309
Whetstone Rocks of. 329
Organic Matter—An Impurity of Clays. 40
Orthoclase 30
Orton, Edward, Sr., Quoted 7, 35, 376, 380, 382
Orton, Edward, Jr., Quoted 28, 48, 54, 76, 132, 134, 137, 143, 165
Otter Creek—Clays Along 78
Otter Creek Coal Company 55
Owensboro—Clays in Vicinity of 87
Owen County—Clays of 83
Report on Mines of 439

Paolia vetusta—Smith 337, 356
Parastacinæ 476
Parke County—Clays of. 47
Report on Mines of 439
Sandstones of. 212, 250
Patricksburgh—Clays in Vicinity of 83
Coal in Vicinity of. 84
Patoka River 330
Pavements Brick—Formation. 152
Requirements of 155

PAGE.
Paving Brick . . . . See Brick, Paving
Perry County—Clays of 123
Report on Mines of 451
Sandstones of 314
Petersburgh—Clays in Vicinity of 111
Petroleum—Area of Indiana Found in 12
Average Life of a Productive Well 13
Future Production of in Indiana 12
Production of in Indiana 1888-1895 . . . . 12, 471
Quality o Indiana Product 471
Wells Completed in Indiana in 1895 12
Wells Completed by Counties in 1895 472
Pike County—Clays of 110
Report on Mines of 445
Plasticity of Clays—Cause of 26
Plunger Brick Machines—Relative Value of 141
Porter, Dr A W.—Kaolin on Land of 103
Portland Mills—Sandstones in Vicinity of 244
Portland—Sandstones in Vicinity of 278
Portland Stone 306
Posey County 42
Poston Block 62
Potash—An Impurity of Clays 27, 39
Potassium Carbonate 30
Potteries—At Annapolis 49, 174
Bloomingdale 48, 174
Brazil 78, 174
Cannelton 124, 174
Clay City 81, 174
Evansville 174
Huntingburg 107, 174
Rockville 174
Shoals 101, 174
Spencer 174
Worthington 89, 174
Potter's Clay—At Bloomingdale 47
Brazil 78
Cannelton 124
Clay City 81
Coke Oven Hollow 49
Covington 63
Huntingburg 107
Independence 302
Loogootee 101
Mineral City 87
Owensboro 87
Shoals 101
Sullivan County 94
West Montezuma 69
Worthington 89
Potter's Clay—Necessary Properties of 171
Pottery—The Manufacture of 171
Princeton—Clays in Vicinity of 113
Coal in Vicinity of 114
Prospect Hill Mine—Clays of 95
Pseudopecopteris muricata (Brongn) 354
Pyrites 37, 67, 125, 260

Quartz—Abundance of, in Nature 29
Composition of 29

	PAGE.
Raccoon Creek—Outcrops of Sandstone Along	230, 248
Rattler Test for Paving Brick	150
Reelsville—Sandstones in Vicinity of.	223
Refractory Clay Products—Manufacture of.	168
Reports, Geological—Number Printed	5
To Whom Distributed	5
Residual Clays—Definition	31
Rice, W. H.—Quarry of, near Bainbridge.	230, 318
Riverside—Sandstones in Vicinity of.	287, 317
Rockingham ware	123
Rockport—Clays in Vicinity of	121
Rocky Run Slip-Clay	56
Sands—Occurrence of in Indiana	20
Sandstones of Indiana	17, 188
Analyses of	322
Bibliography of	323
Cement of	189
Definition	188
Distribution of	195
Fitness of for Lintels	17
Geologic History of	195
Grains of, Composition and Character	188
Production of	194
Source of Material of	197
Uses of.	193, 194
Varieties of	191, 193
Sankey, Hon. Jas. M.—Clays on Land of	74
Scovell, Dr. J. T	73
Screens for Clay	140
Sedimentary Clays.	32
Seeleyville—Clays in Vicinity of	76
Selenite	81, 110
Sewer Pipe—Manufacture of	164
Statistics of Factories in Indiana	167
Shades of Death	267
Shales—Arenaceous	45
Argillaceous	45
Bituminous	44
Calcareous	46
Comparative Value of for Paving Brick	137
Definition of	25, 32
Fossils of	44
Micaceous.	46
Origin of	42
Uses of	18
Varieties of	32
Shawnee Creek—Outcrops of Sandstone along	282
Shryer, Joseph—Sandstone on Land of	311
Shuster, J. W.—Clays on Land of	60
Siderite	20, 38
Sigillaria.	332
Silica—Composition of.	29
Impurity of Clays	36
Simpson, Benj.—Clays on Land of	80
Slip Clay—Albany.	47, 56, 78
Analyses of.	57
Rocky Run.	56
Soda—An Impurity of Clays	27, 39
Soils—Deterioration of	15
Drift, Composed of	14
Need of Analyses of	15
Value of, Comparative	14

	PAGE.
Spencer County—Clays of	121
Sphenopteris hoeninghausii (Brongn.)	354
St. Anthony Sandstone	312
Steatite.	45
Stiff Mud Brick Machines—Relative Value of	141
Stigmaria	44, 63
Stone Bluff—Clays in Vicinity of	60
Sandstones in Vicinity of	275
Stone Fence Posts	69
Stone Pumps	77, 166
Stoneware—Manufacture of	172
Statistics of Factories of	174
Stoneware Clays—Analyses of.	48
Necessary Properties of	171
Sugar Mill Creek—Clays along	50
Sandstones along	258
Sullivan County—Clays of	91
Report on Mines of	448
Sulphate of Iron	38
Sulphur Balls	37
Sun—The Source of all Energy	6
Superior Block Coal Company	57, 440
Switz City—Clays in Vicinity of	88
Talc	45
Tempering Clays	140
Terre Haute Brick and Pipe Company	65, 73, 167
Terre Haute—Clays in Vicinity of	74, 76
Terre Haute Pressed Brick Company	75, 177, 180
Thompson, Maurice	41, 105
Thorp, H. T.—Clay on Land of	73
Titanic Acid—An Impurity of Clays	39
Toledo, St. Louis and Kansas City Railway	61, 65, 70
Trenton Limestone	383, 387
Tripoli	109
Troy—Clays in Vicinity of	123
Troy-ware	123
Under-clays	See "Fire-Clay."
Vandalia Railway	72, 76, 217, 223
Vanderburgh County—Clays of	116
Report on Mines of	450
Veedersburgh—Clays in Vicinity of	61
Vegetable Cell—Office of.	7
Vermillion County—Clays of	65
Report on Mines of	446
Vigo County—Clays of.	71
Report on Mines of	446
Vincennes—Clays in Vicinity of	95
Vitrified Products—Standard Composition of Clays Suitable for	54
Wabash Paving Brick Company	61
Wabash Railway	59, 287, 293
Wabash Roofing Tile Company	51, 52, 58, 79, 176
Walnut Creek—Outcrops of Sandstone along	226, 229
Warrick County—Clays of	119
Report on Mines of	452
Washington—Clays in Vicinity of	97
Watson, Little & Co.—Clays at Mine of	92
Weathering of Clays	26, 139
Weaver Bros	77, 166

PAGE.
Wells County—Oil Wells Completed in, in 1895 473
Wheat—Constituents of Soil Necessary to Production of 14
Whetstone Rocks—Beds of in Indiana 345
Bibliography of 336
Historical Sketch of 338
Manufacture of 339
Markets for 345
Output of in Indiana 341
Report on 329
Structure of 339
Uses of 340
White, David—Report on Fossil Plants of Whetstone Beds 354
Williamsport Stone Company 295

Zinc Blende—Occurrence of in Indiana 20